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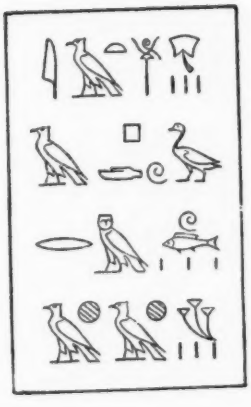

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THE JOURNAL OF WILDLIFE MANAGEMENT

VOLUME 24 OCTOBER 1960 NUMBER 4

SOME EXPERIMENTS IN THE BAITING OF CARP

D. Homer Buck[1], *Maurice A. Whitacre, and Charles F. Thoits III*

Illinois Natural History Survey and Illinois Department of Conservation, Dundee, Illinois

The carp (*Cyprinus carpio*) is usually considered a menace to sport fishing interests, and since about 1920 has been the object of intensive and costly control programs by many conservation agencies. The biology of the carp, including its many undesirable characteristics, has been surveyed by Sigler (1958), who also reviews the various techniques that have been employed in carp control. Of those techniques now in use, each is adaptable only under certain conditions. Seining may be extremely efficient in some waters (Neess, *et al.*, 1957), but many lakes either are too deep to be effectively seined, or they present physical obstructions. Complete eradication of carp with rotenone is undoubtedly the most efficient method, but is often too costly or otherwise impractical. For reservoirs where water levels may be controlled, Shields (1957) has recommended a technique for exposing the eggs of carp to desiccation by lowering water levels. This method is adaptable for many large flood-control reservoirs. Electric seines or shocker boats, artificial barriers, and various kinds of nets and traps are often employed, but each has definite limitations. There still are a great many lakes and reservoirs having nuisance carp populations in which none of these techniques can be successfully applied.

The purpose of the project reported here was to test the value of baiting carp with corn as a method of concentrating these fish prior to their entrapment and destruction through the use of rotenone. If baiting were successful, it would permit a selective kill of carp with a minimum expenditure of manpower and rotenone.

The project was originally suggested by Sam A. Parr, Illinois Department of Conservation. The writers are indebted to Rudy Stinauer, Illinois Department of Conservation, for technical assistance in the 1956 work, and to Walter J. Summers and family for help in collecting and sorting the fish killed with rotenone at Slocum Lake. We also wish to thank George W. Bennett and R. Weldon Larimore for constructive criticism offered during preparation of the manuscript.

TEST AREAS

Slocum Lake.—This lake was chosen as the initial site for the investigation because it was known to have a large carp population and because it contained an area suitable for baiting which could be blocked off with a minimum of equipment.

Slocum Lake is located in Lake County, approximately 1 mile southeast of Island Lake, Illinois. It is of glacial origin and quite typical of many lakes in northeastern Illinois. The principal source of inflow is a small creek which drains nearby Bangs Lake. Original drainage was to the northwest into Cotton Creek, a tributary of the Fox River. In the interests of a real estate development, the normal level of the lake was lowered approximately 4 feet, about 1918, by dredging a new drainage channel to the nearby Fox River. A control gate regulates the flow into this channel. At present the lake has an area of approximately 225 acres and a maximum depth of about 9 feet. Several narrow channels have been

[1] Buck is employed by the Illinois Natural History Survey; Whitacre and Thoits by the Illinois Department of Conservation.

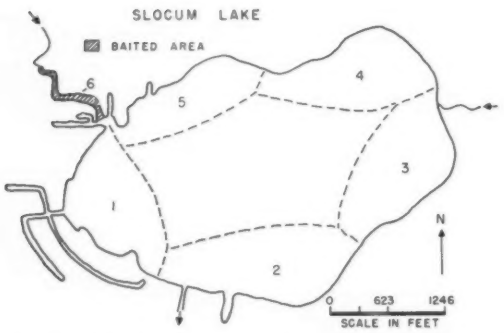

FIG. 1. Map of Slocum Lake showing baited channel and the six areas in which carp were marked in 1957.

dredged from deep water across the gently sloping, shallow, inshore bays to points inward from the natural shore. These channels were dug to increase water frontage and improve docking facilities. The investigations were carried on in one such channel (Fig. 1) owned by Walter J. Summers. The Summers channel is 1,090 feet long, has an average width of 53.6 feet, an average depth of 2.6 feet, and an area of approximately 1.3 acres. At its juncture with the lake the channel is 55 feet wide and from 2 to 4.5 feet deep. Springs in the channel create a slight current into the lake.

Quantitative data on the fish population were lacking, but the predominance of carp was obvious in collections made with an electric shocker and wing nets, as well as in the final collections. Other species caught in the nets included northern pike (*Esox lucius*), largemouth bass (*Micropterus salmoides*), crappies (*Pomoxis annularis* and *P. nigromaculatus*), bluegill (*Lepomis macrochirus*), and white sucker (*Catostomus commersonnii*). Additional species later killed by rotenone included green sunfish (*Lepomis cyanellus*), pumpkinseed sunfish (*L. gibbosus*), black bullhead (*Ictalurus melas*), yellow bullhead (*I. natalis*), brown bullhead (*I. nebulosus*), and channel catfish (*I. punctatus*).

Oxbow and Long Lakes.—In the summer of 1959, we had an opportunity to conduct baiting trials in Long and Oxbow lakes, located at the Fin 'n Feather Club, Dundee, Illinois. Both lakes were densely populated with carp which were to be removed prior to the stocking of experimental populations of other fishes. Oxbow and Long lakes (Fig. 2) were the two lowest in a series of five artificial "flowage" lakes constructed in 1948. Both were originally stocked with largemouth bass and bluegills. Carp and several indigenous species probably gained entrance along with the live minnows (mostly *Notropis atherinoides*) supplied as food for the bass. Principal sources of water are springs, the water from which first flows through a short, artificial trout stream, then drops down through the five lower lakes which are connected by a series of screened overflow pipes or spillways. The main stream of water can be diverted through another channel, as it was during this program; however, sufficient water enters the lower lake system, either from springs or by seepage from upper lakes, to create a small, continuous current through the basins.

Oxbow Lake was so named because of its shape, rather than its origin. It has an area of approximately 1.4 acres, a maximum depth of near 7.5 feet, and an average depth of between 4 and 5 feet. At the time of the experiment it was almost completely free of water weeds and was extremely turbid because of the rooting activities of carp.

At the time of the experiment, Long Lake was partly drained, leaving a surface area of approximately 4.2 acres. Maximum depth was reduced to 6 feet and average depth was between 3.5 and 4 feet. In spite of the

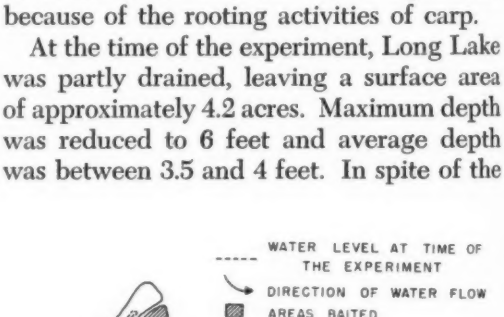

FIG. 2. Map of Oxbow Lake and Long Lake showing areas into which carp were baited.

TABLE 1.—NUMBERS, WEIGHTS, AND POUNDS PER ACRE OF FISHES RECOVERED BY CHEMICALLY TREATING AN AREA BAITED WITH CORN AT SLOCUM LAKE (225 ACRES) FOLLOWING LISTED BAITING PERIODS

	1956				1957			
Baiting periods Time of block-off[1]	7/20–7/23 7/24–5 a.m. (5 a.m.)		8/3–8/20 8/21–3 a.m. (7 a.m.)		7/15–7/28 7/28–10:30 p.m. (7/29–6 a.m.)		7/29–7/31 7/31–9 p.m. (8/1–5:30 a.m.)	
No. applications and total wt. of corn	2 – 400 lb.		6 – 1,300 lb.		9 – 1,090 lb.		1 – 336 lb.	
Kinds of Fish	Number	Pounds	Number	Pounds	Number	Pounds	Number	Pounds
Largemouth bass	5	5	0	0	0	0	0	0
Bluegill	93	19	20	1	–	tr.	–	tr.
Misc. sunfishes	–	11	0	0	75	4	14	1
Crappies	97	24	5	1	22	1	0	0
Channel catfish	19	17	323	174	755	362	74	35
Bullheads	182	30	290	48	28	7	10	3
Carp	967	1,808	2,525	5,800	523	1,692	3,727	5,871
Totals	1,363	1,914	3,164	6,024	1,403	2,066	3,825	5,910
Pounds per acre of lake								
Carp		8.0		25.8		7.5		26.1
Channel catfish		tr.		0.8		1.6		0.2
Others		0.4		0.2		tr.		–
Totals		8.4		26.8		9.1		26.3

[1] Block-off made with a tarpaulin; actual time of rotenone treatment shown in parentheses.

large carp population, the water was clear with extremely dense growths of milfoil (*Myriophyllum* sp.) throughout. Leakage from the lake through a broken drain pipe approximately equalled the inflow, so that the water level remained nearly constant throughout the experiment.

SLOCUM LAKE TRIALS

The number of applications of corn and the total amounts used in the various trials are included in Table 1. The corn was broadcast from a boat. Baiting for all trials was generally similar, except for the following: In the first trial, 1956, the corn was distributed only in the middle section of the channel, in two equal lots of 200 pounds each. In later trials, distribution was mostly in smaller lots, over a greater period of time, and each application of corn was begun 100 feet outside the channel and continued inside to the midsection. In addition, the last 600 pounds of corn used in the second trial in 1956, and the first trial in 1957, were presoaked so as to be in an advanced state of fermentation when distributed. In 1957, four burlap bags, each containing 20 pounds of corn, were weighted and spaced in the channel to provide continuous "scent bait."

A tarpaulin was used to block off the channel and entrap the baited carp. The tarpaulin was suspended by grommets from a stretched wire arranged so that the tarpaulin could be quickly pulled across the mouth of the channel. The bottom edge of the tarpaulin was weighted by short sections of pipe attached in a continuous, end-to-end series. Passage by carp was restricted by pressing the weighted edge into the bottom mud.

Emulsifiable rotenone (Pro-Nox Fish, S. B. Penick & Co., 50 Church St., New York 8, N.Y.) was used in all treatments, applied at the rate of 1 p.p.m. at the times indicated in Table 1. All dead fish that surfaced were collected. For trial 1, 1957, dispersal of the rotenone was delayed from the time the channel was blocked off at 10:30 p.m., July 28, until 6 a.m., July 29. During this interim many carp escaped through holes pushed between the ends of the tarpaulin and the banks of the channel. For this rea-

son the channel was rebaited with an additional 336 pounds of corn on the 29th. The channel was again closed at 9 p.m., July 31, and rotenone was applied immediately to the channel for approximately 150 feet inside the tarpaulin. This prevented the carp from escaping around the ends of the tarpaulin before the remainder of the channel could be treated at 5:30 a.m. the following morning.

Most of the fish killed in all four trials were carp (Table 1). In the last trial, 1957, the total recovery of all fish was 5,910 pounds, of which 5,871 pounds, or approximately 99.3 percent, were carp. This represented a kill of 4,516 pounds of carp per acre of baited area, or 26.1 pounds of carp per acre for the lake. Among the other species of fishes only bullheads and channel catfish were prominent in all four trials, suggesting that they also were attracted by the corn. Largemouth bass, bluegills, crappies, and the miscellaneous sunfishes were prominent in only the first trial, 1956, but were either absent or poorly represented in subsequent trials. The numbers of these species killed by the first treatment probably indicated (1) their normal abundance in the channel prior to baiting, and (2) that the first baiting period of 4 days was too short to have either soured the corn or concentrated the carp to a sufficient degree to have influenced the distribution of the centrarchids. The scarcity of these species in later trials, involving substantially longer baiting periods, indicates they were not attracted to the baited area, and were probably forced out of it by the smell of the sour corn or by the great concentration of carp. This situation was particularly evident in the results from the first trial in 1957, which occurred 11 months after the last previous treatment, a sufficient time interval to have permitted repopulation of the channel area by the centrarchids. The scarcity of these species in the collections suggests they were repelled from the baited area, and indicates that large numbers of carp can be concentrated and killed with small loss of game fishes.

Greater returns from the later trials than from the first indicated the value of the longer periods of baiting. Use of presoaked corn was probably also important. With reference to the last trial, the table may be misleading with respect to the length of the baiting period. This last baiting period was actually continuous with the preceding

TABLE 2.—NUMBERS, WEIGHTS, AND POUNDS PER ACRE OF FISHES RECOVERED BY CHEMICALLY TREATING BOTH INSIDE AND OUTSIDE A BAITED AREA OF LONG LAKE (4.2 ACRES)

Baiting period	6/25–7/5 (10 lb./day); 6/25–30 lb.; 7/6–25 lb.
Time of block-off	7/6–8 p.m.
No. of applications and total wt. of corn	11 – 185 pounds

Kinds of Fish	Inside Baited Area			Outside Baited Area		
	Number	Pounds	Percent of Wt.	Number	Pounds	Percent of Wt.
Largemouth bass	36	3	4.1	–	70	95.9
White crappie	4	1	7.1	–	13	92.9
Misc. sunfishes	–	19	4.4	–	413	95.6
Channel catfish	3	8	28.5	–	20	71.5
Bullheads	5	1	6.7	–	14	93.3
White sucker	4	1	2.9	–	33	97.1
Carp	159	251	24.8	–	761	75.2
Totals	211	284	17.6		1,324	82.4
Pounds per acre of lake						
Carp		59.8			181.2	
Channel catfish		1.9			4.8	
Others		6.0			129.3	
Totals		67.7			315.3	

period since much of the previously distributed corn was undoubtedly still present and the "scent bags" were still intact.

LONG LAKE AND OXBOW LAKE TRIALS

Trials at Long and Oxbow Lakes were similar to the 1957 trials at Slocum Lake, except that all corn was presoaked, and the entire lakes were chemically treated both inside and outside the baited areas. The baited areas differed from that in Slocum Lake in that each represented a section of the lake proper (Fig. 2).

The baited area of Long Lake was blocked off and treated on both July 6 and 7 (Table 2). No additional carp were drawn to the corn the second day because of the high concentration of rotenone still present. The data therefore represent the kill made on July 6.

The total collection of carp in the baited area was 251 pounds, only 24.8 percent of the total weight of carp collected from the entire lake. This was not considered to represent a successful degree of concentration of carp for a lake of this small size (4.2 acres). The extremely dense milfoil may have reduced water circulation and inhibited movement of the carp. Probably more important was the location of the baited area with respect to natural currents in the lake. As may be seen in Fig. 2, the baited zone was in the downstream section of the lake. Water movement was past the mouth of the baited cove and out the broken drain. Had the bait been placed in the upper end of the lake, the current thus being used to transport the scent of the bait, it might have been much more effective.

Statistics on the baiting trial in Oxbow Lake are shown in Table 3. The 602 pounds of poisoned carp collected inside the baited area represented 93.6 percent of the lake's total carp population. This kill reduced the lake's carp population at the rate of 435.7 pounds per acre.

OBSERVED FEEDING PERIODS OF CARP

There is evidence from Clear Lake, Iowa (Carlander and Cleary, 1949) that larger carp tend to frequent the shoal areas during daylight hours but move to deeper water at night, whereas Sigler (1958) believes that normal inshore movement of carp in Utah may be only at night. Normal behavior patterns may be disrupted by the abnormal

TABLE 3.—NUMBERS, WEIGHTS, AND POUNDS PER ACRE OF FISHES RECOVERED BY CHEMICALLY TREATING BOTH INSIDE AND OUTSIDE A BAITED AREA OF OXBOW LAKE (1.4 ACRES)

Baiting period	6/25–7/5 (10 lb./day); 7/7–25 lb.
Time of block-off	7/7–8:30 p.m.
No. of applications and total wt. of corn	11 – 165 pounds

Kinds of Fish	Inside Baited Area			Outside Baited Area		
	Number	Pounds	Percent of Wt.	Number	Pounds	Percent of Wt.
Largemouth bass	54	1	20.0	–	4	80.0
White crappie	38	1	50.0	–	1	50.0
Misc. sunfishes	–	3	23.0	–	10	77.0
Channel catfish	1	2	100.0	0	0	0.0
Bullheads	1	1	100.0	0	0	0.0
White sucker	0	0	0.0	–	1	100.0
Carp	1,114	602	93.6	120	41	6.4
Totals	1,208	610	91.4		57	8.6
Pounds per acre of lake						
Carp		430			29.3	
Channel catfish		1.4			–	
Others		4.3			11.4	
Totals		435.7			40.7	

TABLE 4.—COUNTS OF CARP SURFACING AFTER ELECTRIC SHOCKER STIMULATION DURING CONTINUOUS CIRCUITS OF THE BAITED CHANNEL AT SLOCUM LAKE, JULY 26–27, 1957

Time of Circuits	Number of Carp
4:30 p.m.	276
8:30 p.m. (dusk)	358
12:05 a.m.	260
3:45 a.m.	37
6:15 a.m.	42

influence of baiting. Some commercial fishermen believe that carp enter shallow, baited areas to feed in late evening and move to deeper waters when their appetites have been satisfied. Fishermen further believe that this outward movement begins before dawn, and lay out their seines accordingly before daybreak.

The abundance of carp in the baited channel of Slocum Lake was observed approximately every 4 hours throughout the night of July 25 in order to determine the time of day when peak numbers were present. At this time the channel had been baited for 10 days. The counts (Table 4) represent numbers of carp sighted when caused to surface by the stimulation of the electric shocker while making one continuous circuit about the perimeter of the channel. Counts during the hours of darkness were made with the aid of a floodlight mounted in the boat and powered by the 120-volt outlet of the generator. The highest count was made at dusk, between sunset and normal darkness (Table 4), but it was still not known whether the peak occurred just before or just after this time. The greatest activity, determined by observations of surface disturbances and rising gas bubbles, occurred at dusk and for approximately 2 hours thereafter.

EFFECTIVE DRAWING RANGE OF SOUR CORN

To determine the distance over which carp could be attracted to the sour corn, in six areas of Slocum Lake (Fig. 1) a large number of carp were marked, just prior to the 1957 trials, by removal of various fins. Collections were made by electric shocker, and fish were marked and released where caught.

A total of 473 carp were marked, of which only 27 were recovered (Table 5). Of these, 22 had been marked in the channel area, and 5 in Area 5 immediately adjacent to the channel mouth. No carp were recovered that had been marked in Areas 1, 2, 3, or 4. The apparent conclusions were that (1) individual carp did not circulate completely about the lake but tended to remain in the area where marked, and (2) the baiting had little drawing power beyond the near vicin-

TABLE 5.—NUMBERS AND SIZE DISTRIBUTION OF CARP CAPTURED, MARKED, AND RELEASED IN SIX DESIGNATED AREAS OF SLOCUM LAKE IN 1957

(Numbers of recaptures shown in parentheses)

	Area	Size Groups				Totals
		A 5–10.9 in.	B 11–14.9 in.	C 15–19.9 in.	D 20 in. and up	
Carp marked just prior to baiting	1	58	6	1	1	66
	2	44	20	1		65
	3	28	22	1		51
	4	34	29	5		68
	5	52	21 (5)			73 (5)
	6	36 (3)	31 (11)	1 (1)		68 (15)
Totals		252 (3)	129 (16)	9 (1)	1	391 (20)
Carp marked after commencement of baiting	6	58 (4)	24 (3)			82 (7)
Grand Totals		310 (7)	153 (19)	9 (1)	1	473 (27)

ity of the baited channel. However, these observations must be restricted to the smaller carp in size groups A and B (Table 5), since we were able to mark only nine carp in group C, and one in group D. There is some evidence that larger carp either ranged more extensively, were attracted to the bait more readily than smaller individuals, or were driving smaller carp out of the area of concentration. For example, of 52 group A carp marked in Area 5, none was recovered, while of only 21 of the larger group B marked in this area, 5 were recovered.

DISCUSSION

The trial in Oxbow Lake demonstrated that effective control can be obtained by one treatment in lakes of this small size (1.4 acres). In lakes up to 10 acres in size, 2 or 3 such operations might effectively reduce the carp population. In larger lakes it would probably be necessary to bait and chemically treat each of several widely separated locations. In intensively managed lakes, certain areas might be established as permanent or semi-permanent baiting areas. To obtain maximum benefit from bait and time invested in preparations, the process should be repeated two or more times, or as often as carp can be drawn to the bait. At Slocum Lake in 1957, carp readily re-entered the baited channel within 36 to 48 hours following a first treatment with 1 p.p.m. emulsifiable rotenone. The second treatment resulted in a much larger kill than the first. Much corn undoubtedly remained uneaten, and the "scent bags" were still intact.

While the bait was highly attractive to carp, it may be only slightly less attractive to catfishes. Relatively large numbers of channel catfish, and lesser numbers of bullheads, were killed in two of the Slocum Lake trials. Since we do not know the comparative abundance of catfishes and carp in Slocum Lake, the comparative degree of selectivity cannot be evaluated. Where desirable, the technique might be employed to reduce noxious catfish populations, but where catfish are valued, it would be advisable to make preliminary tests to avoid the possibility of eliminating both catfish and carp.

Angling for carp where they are concentrated can provide exceptional sport. This was demonstrated at Slocum Lake where local anglers removed hundreds of pounds of carp from the baited channel by hook-and-line fishing after the final trials. The most common practice was to bait the hook with one or two kernels of pre-soaked corn.

A natural cove, or a channel, is an advantage to such a project but not an absolute requirement. In Oxbow Lake a tarpaulin was stretched from one bank to within 10 feet of the opposite bank, as a temporary barrier. Access to the baited area was restricted to this one small opening, through which carp readily entered. In the absence of a suitable cove or inlet, it should be possible to draw carp to temporary enclosures rigged with chicken wire or small-meshed seines, with openings that could be quickly closed left near shore. The type of block-off seine used for sampling with rotenone in Louisiana (Lambou and Stern, 1958) should also prove effective. Every precaution should be taken to close the barrier at the bottom since carp are extremely wary and will stampede with very little provocation.

In lakes having an inflow, it would probably be advantageous to place the bait where its scent would be carried by the current. We had the benefit of only a very weak current in the channel at Slocum Lake and feel we made a serious mistake in not taking advantage of the relatively strong current available in Long Lake.

Consideration should be given to the most advantageous season for such an operation. Late summer offers the advantages of higher water temperatures, which would aid in fermentation of the bait and allow maximum killing efficiency with rotenone. Toxicity of rotenone also dissipates more rapidly in warm water than cold, which allows for an earlier repetition of the treatment in a particular area. An early-summer operation would offer much the same advantages, as well as a longer growing season in which

the surviving game fish might benefit from the reduced density of carp. If rotenone treatment is done too early, however, the reduction in numbers might induce increased reproduction by surviving carp. This seems to have occurred in Long Lake where we failed to get a complete kill of carp in the July 8 treatment, and large numbers of carp were spawned after this date. The same phenomenon had been reported for bluegill in Tennessee (Cobb, 1954). If the technique were attempted in late fall or early spring, the lower water temperature would necessitate larger amounts of rotenone and might reduce effectiveness of the bait. However, in cold weather the corn could be fermented indoors.

Corn proved effective, but other foods or grains might prove more effective, as well as more economical. Oats, soybean cake, cottonseed cake, bread, or dried milk, either singly or in combinations, are other possible baits.

SUMMARY

Experiments were carried out on 225-acre Slocum Lake, 1.4-acre Oxbow Lake, and 4.2-acre Long Lake to test the use of corn for baiting carp to a small area where they could be enclosed and killed with rotenone. Sour corn seemed to repel most other fishes so that large numbers of carp, and possibly catfishes, could be concentrated and killed with small loss of game fishes. Removal of 93.6 percent (by weight) of the lake's carp population was obtained by one treatment of the baited area in 1.4-acre Oxbow Lake. Results indicated 2 or 3 repetitions might be required in lakes up to 10 acres in size. Control in lakes as large as Slocum (225 acres) would require several treatments in each of several widely separated areas. With continuous baiting, carp can be reconcentrated at fairly short intervals of time. At Slocum Lake, 5,871 pounds of carp were attracted to the baited area and killed there within 36 to 48 hours following a first treatment with rotenone. The best use of the technique would involve establishment of permanent, continuously baited areas, where carp could be killed as often as they could be concentrated at the bait.

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TEST OF SHELTER REQUIREMENTS OF PENNED WHITE-TAILED DEER

William L. Robinson[1]

Maine Cooperative Wildlife Research Unit, University of Maine, Orono, Maine

Most research on the white-tailed deer (*Odocoileus virginianus*) has been focused upon its requirements during the winter months, its period of greatest physical hardship. The intricate and complex aspects of the food and nutrition of deer have been the subject of much inquiry in the past 30 years, but it has not been until the last decade that the value of shelter in winter deer yards

[1] Present address: Department of Zoology, University of Toronto, Toronto, Ontario.

began to receive recognition. Plans for deer yard management now include consideration of cover as well as food.

It is well known that good deer yards must contain a suitable interspersion of food and cover. What constitutes suitable cover, however, has not been clearly established. Evaluation of cover alone, as it affects the condition and behavior of deer, has remained a nebulous phase of research on this animal.

The present study was undertaken to observe and measure the effects of sparse coniferous shelter upon white-tailed deer fawns. This project, conducted at Orono, Maine, during the winters of 1957–58 and 1958–59, was administered jointly by the Maine Department of Inland Fisheries and Game and the Maine Cooperative Wildlife Research Unit (University of Maine, U. S. Fish and Wildlife Service, Wildlife Management Institute, and Maine Department of Inland Fisheries and Game cooperating). It was financed largely by Pittman-Robertson Project W-37-R.

Many individuals assisted the author during the investigations. Special appreciation is extended Howard L. Mendall and Malcolm W. Coulter of the Maine Cooperative Wildlife Research Unit, and John D. Gill, Maine Department of Inland Fisheries and Game, for organizing the project and providing necessary guidance during the study. J. Franklin Witter of the Department of Animal Pathology, University of Maine, generously contributed services and facilities for handling and examining deer.

REVIEW OF LITERATURE

A search of the literature revealed no controlled experiments evaluating the relationship of cover to the welfare of deer. In the field of livestock management several researchers (Sanborn, 1892; Buckley, 1913; Dice, 1940; and Brody, 1945) have reported upon the resistance of cattle to winter exposure. Their findings in general were that cattle, given adequate food, were able to withstand prolonged lowered temperatures without notable decline in milk production or losses of weight.

By contrast with the situation in cattle, evidence of apparent dependence of white-tailed deer upon winter shelter has been gathered from field observations of several workers (Gerstell, 1938; Hamerstrom and Blake, 1939; Severinghaus, 1947; Webb, 1948; Cheatum, 1951; and Gill, 1957). Their observations have strongly indicated that good winter shelter is a prime requirement for a deer yard. Dependence upon cover seems especially important in late winter when, in many overbrowsed areas, the deer are in poor condition.

METHODS

Three groups of fawns were kept at controlled, low levels of nutrition in three 1½-acre enclosures. Each pen or enclosure had a different coniferous cover density, classified as sparse, moderate, and dense. The basis for this classification was cover density found in deer yards in Maine, according to Gill (1957). The pen considered to have sparse cover was given a heavy commercial pulpwood cutting prior to the experiment so that no trees larger than 5 inches d.b.h. remained. Crown cover in this area was about 34 percent. The pen having moderate cover contained an all-aged mixture of hardwoods and softwoods with coniferous crown cover of about 55 percent. The area selected for its dense cover was an early-mature stand of white pine (*Pinus strobus*), hemlock (*Tsuga canadensis*), spruce (*Picea* spp.), and balsam fir (*Abies balsamea*). Crown cover in this pen was about 73 percent. The topography of the pen area was generally level, with less than 10 feet of elevation separating the highest ground from the lowest. Fig. 1 is an aerial view of the study area.

The climate at Orono during the period of study was characterized by temperatures ranging from an infrequent minimum of –20°F. to an occasional maximum of +35°F. Total annual snowfall was less than 100 inches with accumulations seldom exceeding 2 feet. Prevailing winds were from the northwest.

Climatic influences were measured in each pen by means of portable instruments that were read daily and relocated every

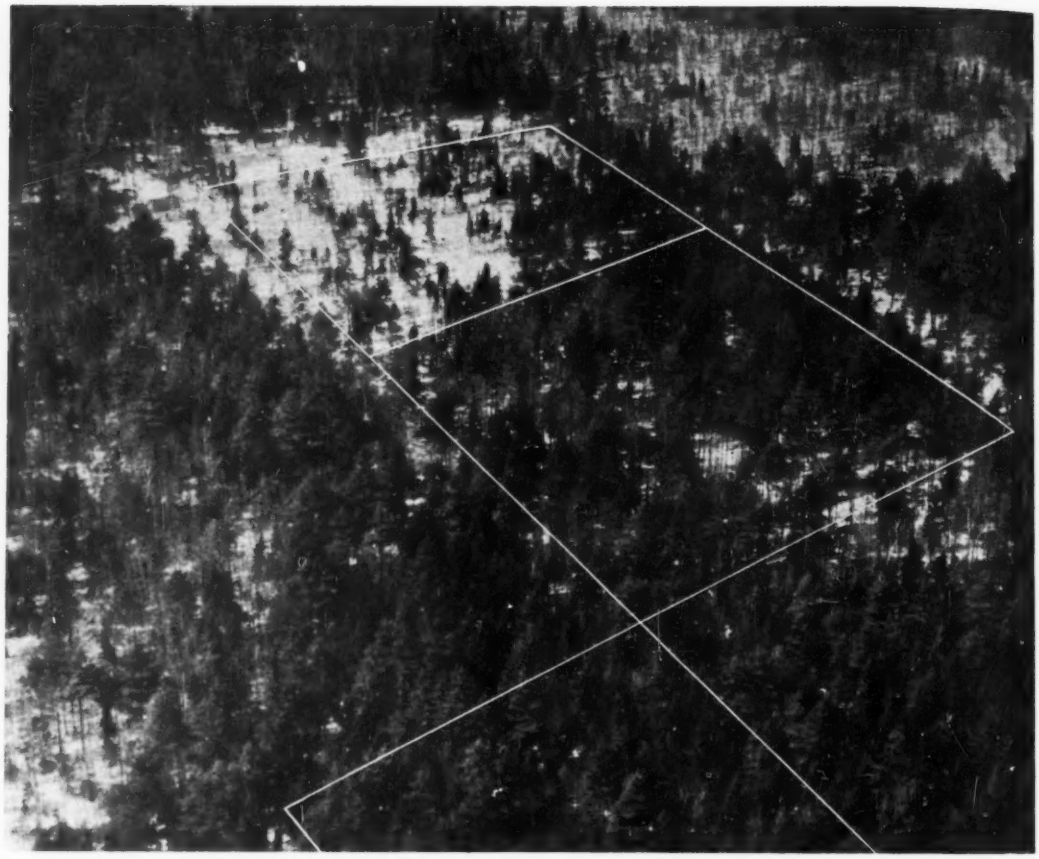

FIG. 1. Aerial view of study area from the southeast. White lines indicate fenced boundaries of pens. Top, sparse cover; middle, moderate cover; and lower, dense cover.

second day according to a systematic grid pattern. The instruments were placed on stands about 2 feet high to record conditions at the height of a standing deer. Temperatures were recorded with maximum-minimum thermometers, wind movement with improvised recording anemometers, and humidity with a sling psychrometer. Snow depth was measured on an 80-sample transect in each pen.

The animals studied were fawns, from 6 to 8 months old, weighing between 35 and 90 pounds. In the first winter one male and one female were placed in each pen on December 19. These animals had been trapped as wild fawns at the Swan Island Game Management Area. In the second winter three males and two females were kept in each pen. Twelve of these had been reared in captivity at the State Game Farm, Gray, and were accustomed to humans. The remaining three had been wild-trapped at Swan Island. Each pen ultimately held one wild-trapped and four semitame animals. These deer were obtained for study on the following dates: October 3 (1 semitame), October 29 (11 semitame), and December 19 (3 wild). The experiment was concluded in the third week of April the first year and in the fourth week of March the second year.

An artificial diet consisting of a 4:1 combination of Eastern States Champion A-14 goat ration and Eastern States alfalfa pellets was provided. The quantity of feed given to the deer was held below an estimated maintenance level and the ration was reduced as the season progressed in an attempt to simulate natural food conditions.

As the deer in the first season's study showed only small declines in condition, the diet during the second winter was reduced to about 60 percent of that of the previous winter. Natural browse in the pens within 7 feet of the ground was removed so that feeding could be controlled and equalized for each group of deer.

Prior to release in the pens each deer was weighed. Measurements were made of body girth at the heart and hind foot length, and blood samples were taken. These operations were duplicated at the conclusion of the experiment in late winter for comparison with early winter measurements. Although more frequent measurements may have been desirable, experienced deer researchers in New Hampshire (Helenette Silver, personal communication) and in Michigan (Louis Verme, personal communication) advised against repeated handling of the deer. Information from measurements was supplemented by close observation of the appearance and behavior of each deer throughout the winter. The deer were fitted with distinctively colored collars for individual identification. Specifications for these collars were taken from Progulske (1957).

The condition of each deer was evaluated by three methods: (1) a "condition factor," consisting of a weight-skeletal size relationship; (2) periodic visual estimates of condition; and (3) fat content of femur marrow. The first of these indicated condition at the beginning and end of the study (the two times when measurements were taken), the second, during the study, and the third, at the end only. Conclusions regarding shelter requirements were based upon a comparison of the average changes that occurred in the condition of the groups of deer.

The "condition factors" were derived as follows: A regression was calculated in which autumn weights and hind foot lengths of all experimental animals were plotted against each other. The resulting curve (Fig. 2) was used to obtain average or "expected" weights for given hind foot lengths. Each condition factor was obtained by dividing actual weight by the expected weight of the deer for its hind foot length. Condition factors of the deer in both fall and spring were obtained by comparison with the same regression line. The numerical values of the condition factors ranged from 0.49 for a starved animal to 1.25 for a prime, fat doe.

Periodic visual estimates of condition were made by examining body contours and vigor of each deer. A scale with categories ranging from 10, a deer in prime condition, to 0, a dead animal, was used to rank the appearance of each deer. Designations for each category follow:

10. A prime, fat animal, with smooth lines, heavy legs, and round, full shoulders.
9. A deer just beneath optimum appearance. Shoulders, legs, and back are not fat-appearing but still smooth and full.
8. An animal still in good condition, but showing either a slight definition about the shoulders or a trace of slenderness in the legs.
7. This point might be considered an "average" condition. Neither fatness nor thinness is apparent, but on close inspection there can be seen a slight demarcation between neck and shoulders or, if one can compare with deer in better condition, more slender legs.
6. An animal in which *one* of the following characteristics is noted: (a) definition of neck from shoulders; (b) the upper arm (humerus and its musculature) distinct from the chest; or (c) noticeable thinness of the legs.
5. A condition in which *two* of the characters listed in number 6 can be noted.
4. A thin animal. All *three* of the characters listed in number 6 are evident.
3. A condition in which the hide fits loosely about the neck and shoulders. The humerus is still held above a horizontal angle, and in standing the back is still held level. Walking and running still occur without apparent weakness.
2. All the symptoms of malnutrition are

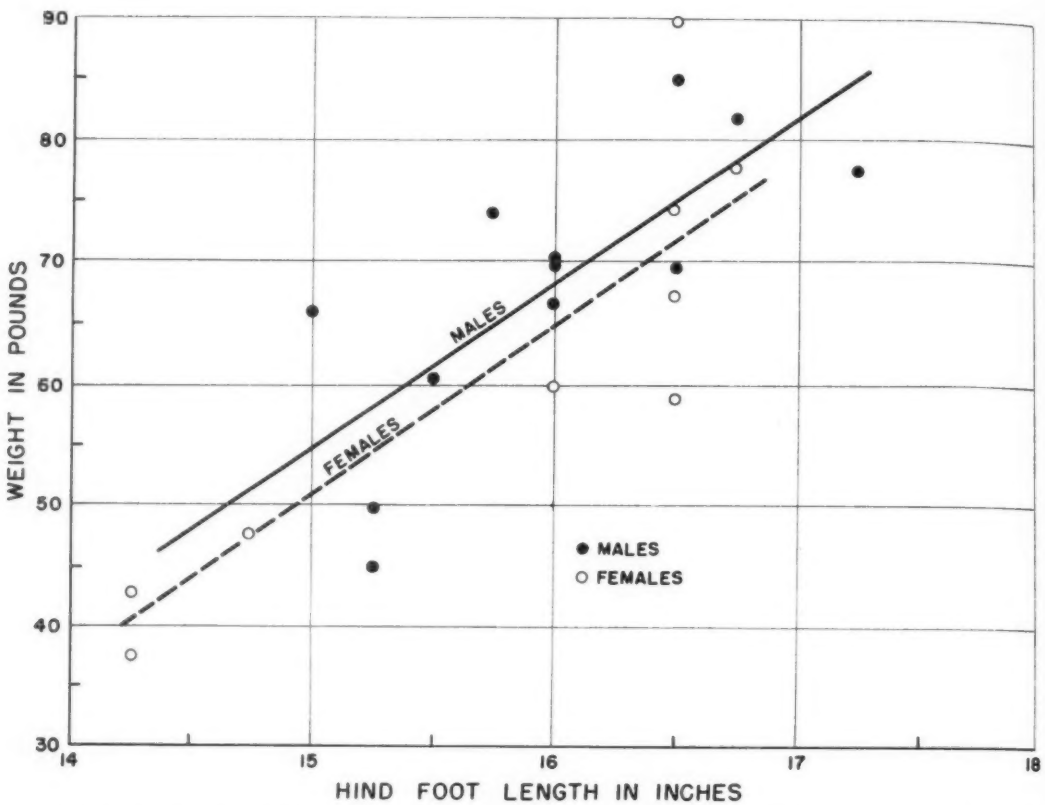

FIG. 2. Regression of weights and hind foot lengths of experimental fawns. Curves represent "expected" weights for deer of given hind foot lengths. Condition factors were obtained by the formula: Actual Wt. at *HFL* x. ÷ "Expected" Wt. at *HFL* x. ($\hat{Y}_{males} = 13.3\,x - 145.0$; $\hat{Y}_{females} = 14.0\,x - 159.9$).

obvious at this point. The legs are plainly thin, the humerus is held at a near-horizontal position, the outline of the scapula is evident and the back is humped or sagged. The deer is still able to walk and run, but running is not performed readily or for distances of more than 30 yards or so.

1. A deer that has reached a stage of malnutrition from which recovery seems impossible. The whole appearance is one of weakness, walking is uncertain and on spread toes, and running is not possible.
0. A dead animal.

The deer were killed for autopsy at the conclusion of the study in early spring. Fat content of the femur marrow was determined by ethyl-ether extraction, using methods described by Cheatum (1949).

Consideration of the limitations of the study must be made. Five principal limitations were present in the methods of investigation: (1) The numbers in each sample were too small for statistical evaluation. (2) The restricted range brought about by the confines of the pens and by regular daily provision of food did not require the deer to use as much energy as would be expected under natural conditions. (3) The predominantly semitame animals in the second winter's study undoubtedly displayed behavior characteristics different from those of wild deer. (4) Although persistent efforts were made to remove all available browse before the study, a small, variable amount was present in each pen from limbs weighted down by snow, trees blown over, and squirrel cuttings. (5) As basic information about the measurement of condition of living deer

was scarce, it could not be positively determined whether the methods employed were accurate. Further research is needed to establish criteria to describe condition of living deer.

RESULTS

Environmental Conditions

Nightly minimum temperatures measured at stations on a grid pattern were significantly lower in the cutover area than in the moderate and dense shelter situations. Temperatures in locations which the deer had selected as bedding sites, however, showed no significant differences among pens.

Wind movement was greatest in the cutover area. About nine times as much accumulated wind mileage was recorded in the cutover pen as in the dense shelter, and about three times as much in the moderate cover. Even in bedding areas, about one and one-half times as much wind movement occurred in the cutover pen as in the moderate shelter and three times as much as in the dense cover.

Humidity readings were variable from place to place and differences between pens were not consistent. It is believed that humidity was a minor influence.

Snow depths were generally greatest in the cutover area. The small size of the enclosures, however, greatly restricted ranging by the deer, and they formed hard-packed trails soon after each snowfall. Snow depth was, therefore, not an important variable in the study.

Deer Condition

In neither year did the condition factor averages indicate that deer in the cutover area showed significantly greater declines in condition than those in moderate or dense cover. The results are shown in Table 1. All deer experienced a loss in the condition factor during the winter.

TABLE 1.—CHANGES IN CONDITION FACTORS OF EXPERIMENTAL DEER

Cover Class	1957–58 Sex	Dom. Pos.	Semitame or Wild-trapped	Condition Factor Fall	Spring	Change	1958–59 Sex	Dom. Pos.	Semitame or Wild-trapped	Condition Factor Fall	Spring	Change
Sparse	♂	1	W	0.98	0.87	–0.11	♂	1	S	0.98	0.79	–0.19
	♀	2	W	0.93	0.76	–0.17	♂	2	W	1.03	0.73	–0.30
							♂	3	S	0.77	0.49[1]	–0.28
							♀	4	S	1.06	0.62[1]	–0.44
							♀	5	S	0.96	0.81	–0.15
Avg.				0.96	0.82	–0.14				0.93	0.67	–0.26
Moderate	♂	1	W	0.93	0.85	–0.08	♂	1	S	1.13	0.82	–0.31
	♀	2	W	1.03	0.86	–0.17	♀	2	S	1.25	0.82	–0.43
							♀	3	S	1.03	0.89	–0.14
							♂	4	S	0.85	0.73	–0.12
							♂	5	W	1.05	0.81	–0.24
Avg.				0.98	0.86	–0.12				1.06	0.81	–0.25
Dense	♂	1	W	0.91	0.79	–0.12	♂	1	S	1.02	0.78	–0.24
	♀	2	W	0.92	—	—	♂	2	S	1.21	0.87	–0.34
							♀	3	S	1.01	0.67	–0.34
							♀	4	S	0.82	0.53[1]	–0.29
							♂	5	W	1.14	0.83	–0.31
Avg.				0.92	—	—				1.01	0.72	–0.29

[1] Died of starvation in March.

Periodic visual estimates of condition likewise showed that deer held in the sparse shelter did not experience condition declines exceeding those in the other two areas.

Analyses of fat content of femur marrows indicated no differences, in the first winter, in final condition among groups of deer. In the second winter, marrow fat content of animals in the cutover area had declined to a lower level than that of those in the moderate and dense cover situations. This was attributed, however, to the generally poorer initial condition of the deer in the sparse cover pen. As selection of individual deer for each pen had been made on a random basis (except for sex), this circumstance was accidental.

Three mortalities occurred in March 1959 as a result of the experimental conditions. Two of the deer that died were in the cutover area and one was in the dense cover. Careful post-mortem examination of these deer revealed the cause of death to be starvation, with no evidence of pneumonia or other effects of exposure. Femur marrow fat in all three cases had been reduced to less than 1 percent.

Behavior

Observations of behavior were centered upon three main factors: (1) total amount of movement about the pens, (2) location and characteristics of bedding areas, and (3) demonstration of dominance among individuals in each group. Because of the broad and complex nature of behavior patterns, many of which were not related to environmental shelter density, a separate paper (Robinson, unpbl. ms.) is being prepared on this subject. A brief summary of the observations on behavior is presented here.

Measurement of total amount of movement by a track-count system showed that during the first winter the deer kept in the open and moderate cover situations sometimes walked about the pens a great deal more than those in the dense cover. On other days their movement was considerably less than that of deer in the dense area so that total recorded movement was about equal for the three groups. The pair of animals in the dense cover were fairly regular in their movements. The differences in activity between groups from time to time could not be explained on the basis of temperature or atmospheric pressure. No unnatural external stimuli such as human disturbance or noises seemed to contribute to the sometimes increased movements of the deer in the light cover. In the second winter no differences in total activity among pens were noted.

Bedding sites were apparently chosen for their protection from wind and for their warmer temperatures, especially during periods of cold weather. A typical bedding site was characterized by having overhead shelter in the form of dense conifers, protection on the north afforded by trunks of trees or by slash, and a southern exposure allowing sunshine to reach the ground.

Final condition of the individuals appeared to be related to dominance position. Those deer that consistently drove the others from the feeding shelter were found to be above average in condition at the end of the study, regardless of their condition at the beginning.

DISCUSSION

The ability of the deer to select and remain in the most favorable microclimate available probably accounts for the negative results of this study. Bedding sites in the sparse cover had minimum temperatures closely comparable to those of bedding sites in the other two pens. In the cutover area the remaining few clumps of trees apparently provided adequate protection from wind. Night temperatures in these clumps were 4 to 5 degrees above those in completely exposed locations nearby. Definite preferences for certain protected sites were demonstrated in the second year when the deer chose the identical bedding sites used by other fawns in the preceding year. In the dense and moderate cover situations there were more acceptable sites than in the cutover area.

The three animals that died of starvation

had been reduced to an unusually low nutritional state before death (marrow fat of less than 1 percent). Cheatum (1951) found deer with 25 percent marrow fat that had succumbed to winter hardship in poorly sheltered areas of the Adirondacks. In the present study 12 of 21 deer had been reduced to a condition in which their femur marrow fat was less than 25 percent. This may not be unusual among fawns, however. Many of these animals appeared to be in a reasonably good state of health. The fact that the animals of the present study were not required to travel through deep snow, or even to range about in shallow snow to seek food, probably allowed the deer to survive longer and reach a lower state of malnutrition before death than would be expected under wild conditions. It is also possible that more severe winters (such as in the Adirondacks) bring about more rapid death by exposure.

Weight losses in the starved deer were also of interest. The two that had been kept in the sparse shelter had lost 16 and 18 percent of their respective late-October weights, while the one in the densely sheltered area had lost 23 percent. The protection afforded by dense shelter possibly enabled the latter animal to survive longer despite its poorer condition. Five other deer in the experiment showed weight losses of more than 16 percent, or more than that lost by the lightest starved animal in the cutover area. One deer, also in the cutover area, had lost 26 percent of its December weight, but a direct comparison with those deer that were weighed in October cannot be made. The conclusion is, however, that individual differences in resistance are probably important factors in deer mortality.

SUMMARY

This study conducted in Maine concerned the effects of winter cover on physical condition of white-tailed deer fawns. During two winters, three groups of fawns were maintained separately in 1½-acre enclosures having either sparse, dense, or moderate coniferous cover. A submaintenance diet was provided equally for each group. The results showed that the deer kept in the sparse shelter suffered no greater declines in condition than those kept in moderate or dense cover. Although more severe climatic conditions generally prevailed in the sparsely sheltered area, the deer selected and spent much of their time in bedding areas which had microclimates similar to those of bedding areas in the other pens. This is given as the primary reason for similar condition losses of the deer in all three pens.

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MALLARD AGE AND SEX DETERMINATION FROM WINGS

Samuel M. Carney and Aelred D. Geis

Patuxent Wildlife Research Center, Bureau of Sport Fisheries and Wildlife, Laurel, Maryland

Aldo Leopold (1933:22) defined productivity as: ". . . the rate at which mature breeding stock produces other mature stock, or mature removable crop." Since sustained hunting must subsist on this annual crop, measuring productivity is one of the basic steps required for the management of any game species. At present, the U.S. Bureau of Sport Fisheries and Wildlife conducts waterfowl production surveys (Crissey, 1957; Stewart, *et al.*, 1958), but does not measure directly the productivity of individual species.

A serious problem encountered in gathering waterfowl productivity data has been the lack of a method applicable to sampling randomly over large areas. The only reliable field technique for determining the age and sex of waterfowl, cloacal examination (Hochbaum, 1942), could be applied by relatively few persons. Techniques, however, have been developed that permit age and sex of gallinaceous game birds to be determined from detached wings or other body parts collected from hunters (Ammann, 1944; Leopold, 1939; and Petrides, 1942). Procedures for gathering data in this manner and some possible applications have been summarized by Blouch and Ammann (1952) and by Dow (1954). Because the Bureau obtains addresses of a sample of waterfowl hunters from its annual mail waterfowl kill survey, it was logical to consider following a similar procedure to gather waterfowl productivity data.

Since ducks can be identified to species from their wings, and early in the fall the age of many can be determined from their rectrices, the wing and tail were considered to be the most promising parts. A small-scale pilot study was conducted in Minnesota during the 1958–59 hunting season to learn whether hunters would be willing to remove these parts and mail them to the Bureau. More than 1,000 wings and tails representing 17 species were received from the 666 hunters contacted. The success of this phase of the investigation proved to be a powerful incentive, and studies to develop methods of age and sex determination were intensified. The mallard (*Anas platyrhynchos*) was studied first because it is the most important species in the kill (Crissey, 1958).

This paper describes criteria used for determining the age and sex of mallards from detached wings. We hope that it will stimulate further study of age and sex determination from wings of waterfowl and of the problems of interpreting data from wing collections.

The writers are indebted to John W. Aldrich and Thomas D. Burleigh of the Bureau of Sport Fisheries and Wildlife for arranging for the collection of many specimens and their storage at the Bird and Mammal Laboratory in Washington, D.C. Specimens also were collected by Arthur S. Hawkins and Robert E. Stewart of the Bureau, Laurence R. Jahn of the Wisconsin Conservation Department, Forrest B. Lee of the Minnesota Department of Conservation, Morton M. Smith and other biologists of the Louisiana Department of Wildlife and Fisheries, Vernon Stotts and Richard N. Smith of the Maryland Game and Inland Fish Commission, and many other federal and state workers. Charles F. Kaczynski and Fant W. Martin of the Bureau processed specimens and helped test the reliability of the technique. Fred Schmid, also of the Bureau, helped in the preparation of photographs.

Materials Studied

Wings from birds of known age and sex were obtained from several sources. During the 1957–58 hunting season, Bureau personnel were requested to collect from hunters the wings and tails of birds that either were banded or had been carefully examined internally. We received 193 mallard wings taken throughout the United States.

In 1958, we also received 75 mallard wings collected during October in Minnesota and 1,194 collected during December in Missouri, Arkansas, and Louisiana. All of these wings were from birds subjected to cloacal examination. Approximately 500 mallard wings and tails were received during the Minnesota pilot study. Wings accompanied by tails containing notched rectrices were assumed to be from immature birds. Arthur Hawkins (personal communication, Oct. 14, 1958) found that 28 percent of the immature mallards he examined in mid-October of 1958 in Minnesota lacked notched rectrices that would have indicated immaturity. Therefore, wings accompanied by tails with unnotched rectrices could have come from either adult or immature birds and could not be considered as known-age material. Methods, therefore, were restricted to sex and age determination from wings.

SEX DETERMINATION

Sex determination should precede age determination since knowledge of the birds' sex facilitates age determination. In general, the coverts of the female wings tended to be browner (less gray) than those of males and also tended to be more broadly edged with a lighter brown. Many wings, however, were intermediate in appearance. Several other characters found useful for determining the sex from detached wings are listed below:

Scapulars.—Vermiculated scapulars were found only on the wings of male birds (Fig. 1). However, scapulars of many males shot in early October lacked vermiculations and were similar to those of females. Thus, some wings could be identified as males but the remainder could have been of either sex. The value of this character was further reduced by many Minnesota hunters who excluded the scapulars from the wings submitted.

Underwing-coverts.—The most proximal underwing-coverts, located between the axillars and the tertials, were barred in females while those of males were vermiculated (Fig. 1). Possibly among adult wings, the sexes could have been separated quite accurately by this character if the humerus had been attached. The character was too variable among immatures to be useful. Unfortunately, much of the material received at Patuxent had been trimmed at the proximal end to eliminate the attached muscle and prevent spoilage. Thus, evaluation and tabulation of this character was incomplete.

TABLE 1.—OCCURRENCE OF WHITE ON TERTIAL COVERTS OF MALLARD WINGS

CLOACAL DETERMINATION		TERTIAL COVERTS	
Sex	Age	Some White	No White
Male	Adult	6	251
	Immature	4	137
	TOTALS	10	388
Female	Adult	188	0
	Immature	119	0
	TOTALS	307	0

White bar anterior to speculum.—The white bar anterior to the speculum on the greater secondary coverts extended at least partially over the tertials[1] on all female wings but terminated at the proximal edge of the speculum on nearly all male wings (Table 1, and Figs. 1 and 2). Ten of the 398 males examined showed some white over the tertials. In six of these that were adults, the white was not continuous with the bar anterior to the speculum, and they could be correctly identified as males on this basis. The four immature wings appeared to be indistinguishable from immature females. A correction factor probably could be used to adjust ratios to compensate for this discrepancy. The white bar was the easiest sex character to use because, unlike the other characters, it was rarely lost when the wing was detached.

[1] Kortright (1943:16) defined tertials as: "the innermost series of flight-feathers. The tertials or tertiaries are, properly, the feathers which grow on the upper arm (humerus), but such feathers are not very evident in most birds and the two or three innermost secondaries; growing upon the elbow, and commonly different from the rest in form or colour, pass under the name of tertials."

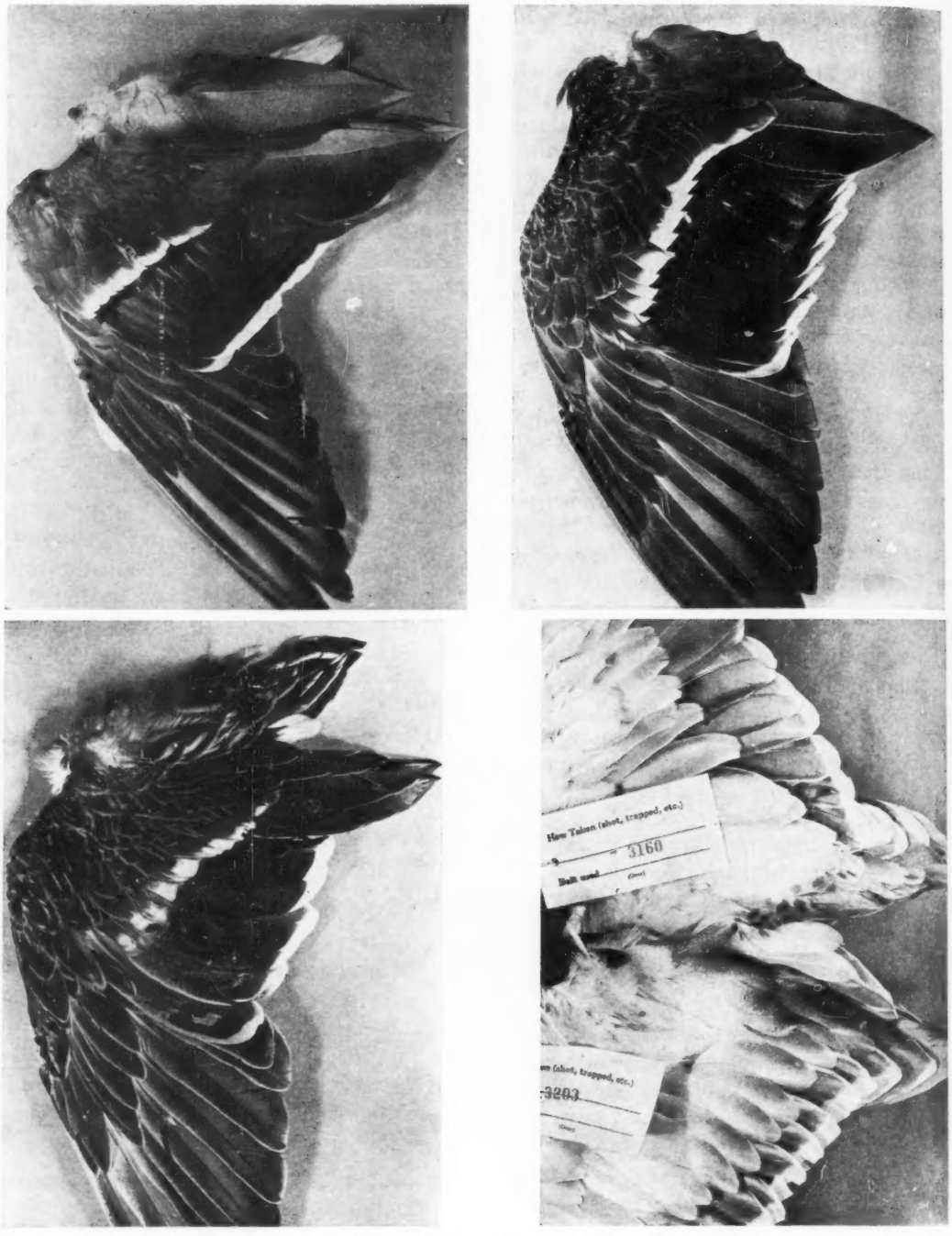

FIG. 1. Mallard wings. *Upper left.*—"Typical" wing from an adult male mallard showing tertial coverts without white edging, and vermiculated scapulars. *Upper right.*—Wing from an adult female mallard showing tertial coverts with white edging, and broad rounded middle coverts. *Lower left.*—Wing from an immature female mallard showing some white in tertial coverts, narrow middle coverts (but more heavily edged than usual), and non-vermiculated scapulars. *Lower right.*—Most proximal under-wing coverts barred on a female (specimen No. 3160) and vermiculated on a male (specimen No. 3203) mallard.

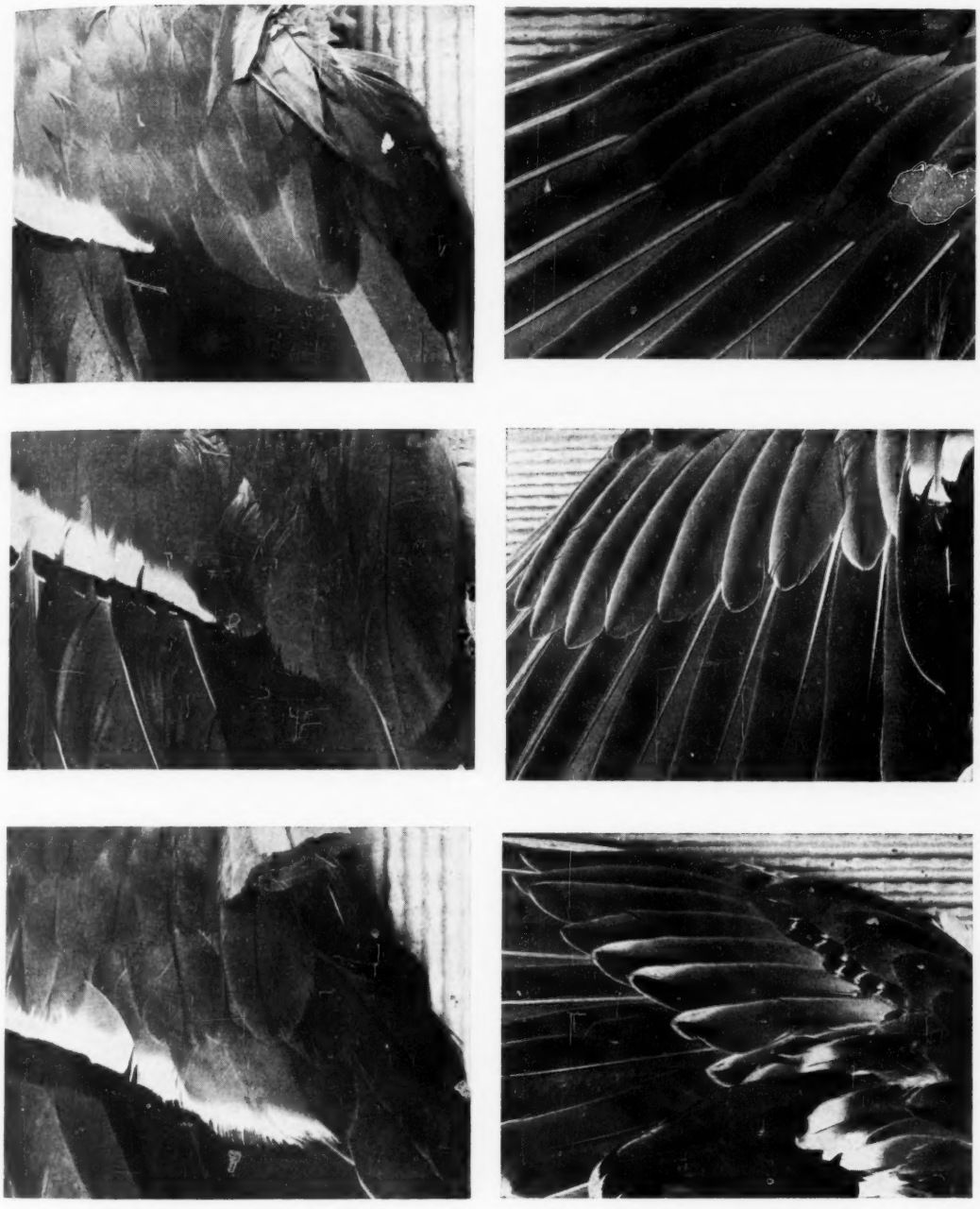

FIG. 2. Mallard wings. *Upper left*—Broad, smooth tertial coverts on the wing of an adult male mallard. *Middle left*—Narrow, frayed tertial coverts on the wing of an immature male mallard. *Lower left*—Frayed tertial coverts on the wing of an immature female mallard. *Upper right*—Unedged primary coverts of a mallard wing. *Middle right*—"Minutely" light-edged primary coverts of a mallard wing. *Lower right*—"Conspicuously" light-edged primary coverts of a mallard wing.

TABLE 2.—OCCURRENCE OF WING CHARACTERS USEFUL FOR AGE DETERMINATION OF MALLARDS[1]

SEX AND AGE	MONTH COLLECTED	TERTIAL COVERTS FRAYED		TERTIAL TIPS FRAYED		NEW TERTIAL SHOWING		MIDDLE COVERT EDGED		MIDDLE COVERT NARROW		TWO MOST POSTERIOR TERTIAL COVERTS NOT WHITE-EDGED		PRIMARY COVERTS LIGHT-EDGED			NUMBER WINGS EXAMINED
		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Wide	Trace	None	
♂ Ad.	Oct.	0	19	0	19	10	11	0	22	0	20	—[2]	—[2]	0	0	22	22
	Dec.	2	226	0	227	0	230	6	224	2	227	—	—	0	2	228	230
♂ Imm.	Oct.	5	18	5	18	12	11	9	14	19	4	—	—	—[3]	18[3]	5	23
	Dec.	79	36	10	104	9	85	58	61	91	25	—	—	—[3]	76[3]	40	119
Total ♂																	394
♀ Ad.	Oct.	0	18	0	18	0	18	16	2	0	18	0	18	0	0	18	18
	Dec.	1	167	1	167	0	170	135	34	1	168	0	169	2	20	154	176
♀ Imm.	Oct.	3	9	6	6	0	12	11	1	10	2	4	8	0	8	4	12
	Dec.	90	17	37	70	3	104	74	33	62	45	52	55	34	56	17	107
Total ♀																	313
Total birds																	707

[1] Some wings were damaged so that all characters could not be checked on every specimen.
[2] Not tabulated for males.
[3] Extent of edging was not recorded.

AGE DETERMINATION

Nearly all the characters useful for age determination were indicators of immaturity. The absence of any one character did not prove that the bird was an adult because no single character was present on all immature wings (Table 2). Age determination from wings is essentially a step-by-step elimination of immatures and classification of the remaining birds as adults. Techniques for determining age are considered separately for the two sexes.

Male Wings

Most males with coverts entirely gray (rather than brown) or gray with a reddish wash were adults. However, exceptions made it necessary to examine the following characters closely in order to determine the age of the wings accurately.

Tertial coverts.—Pronounced fraying of the edge of the tertial coverts, particularly the two most posterior, was quite common on immature birds during the hunting season, but was absent on adults (Fig. 2). Weller (1957) found that the entire juvenile wing plumage of the redhead (*Aythya americana*) was retained throughout the first winter. In the mallard, the frayed feathers presumably were remnants of the juvenile plumage. The tertial coverts of immatures occasionally appeared noticeably narrow but frequently did not.

Tertials.—The tertials of some immature birds were faded and sometimes much frayed at the tips. These feathers apparently also were remnants of the juvenile plumage for they occurred more often on October birds than on December birds and were not present on adults. The sample of November birds was too small for this character to be checked. Because of their light color, the new tertials of males were quite conspicuous as they emerged among the other feathers. Emerging tertials were observed on both adult and immature males during October. The sample of November wings was inadequate for checking this character. After December 1, however, emerging tertials were found only on immatures.

Primary coverts.—Adult males showed no light edging on the tips of the four most distal primary coverts. Either "minute" or "conspicuous" light edging on the inner web of these tips was sufficient to identify immature males (Fig. 2).

Middle coverts.—Immatures more often had narrower middle coverts that were less

rounded and more trapezoidal than those of adults. This character probably was the most difficult to recognize, and practice was required before accurate identifications could be made. Occasionally these coverts were rough and frayed on immatures but not on adults. Some middle coverts showed fine, light edgings on immature but not on adult males.

Female Wings

Though there were exceptions, females with lesser and middle coverts broadly edged with a lighter shade of brown were usually adults. Birds with little or no edging were either adults or immatures. To separate the two age groups accurately we found it necessary to examine the following characters closely.

Tertial coverts.—The tertial coverts of immature females shared the same degree of fraying, fading and narrowness as those of immature males (Fig. 2). Though there were exceptions, immature females usually showed much less white in their tertial coverts than did adult females (Fig. 1). All females showing no white in the two most posterior tertial coverts were immatures.

Tertials.—On immature females the tertials showed the same degree of fraying and fading as on immature males. On females, new tertials were similar in color to the surrounding feathers and therefore emerged inconspicuously. New tertials were rarely noted, perhaps because they were so inconspicuous. Whatever the reason, emerging tertials appeared to be of little use for identifying immature birds.

Primary coverts.—Adults showed "minute" light edging or no light edging. Immatures showed "conspicuous," "minute," or no light edging. Thus, only "conspicuous" light edging (Fig. 2) identified immatures.

Middle coverts.—Narrow, trapezoidal coverts on immature females (Fig. 1) were more apparent than on immature males, possibly because female coverts usually were edged and thus their margins were more clearly delineated. Occasionally the middle coverts of immatures were rough and frayed.

The incidence of the various age characters in a sample of the available known-age material is summarized in Table 2. We were conservative in making this table and listed characters only when they were clearly apparent. Although no single immature character was present on every specimen, only 3 (1.1 percent) of 261 immature wings lacked all characters, and only 15 (3.4 percent) of 440 adult wings showed one or more immature characters (Table 3). At least some of these discrepancies probably were due to incorrect cloacal determinations.

The following keys for determining sex and age of mallards from wings suggest a sequence for examining specific features. Maximum accuracy in classifying wings can

TABLE 3.—INCIDENCE OF IMMATURE CHARACTERS IN MALLARD WINGS[1]

CLOACAL DETERMINATION		Month Collected	NO. OF IMMATURE CHARACTERS PRESENT						No. Wings Examined
Sex	Age		0	1	2	3	4	5	
Males	Adult	Oct.	22[2]	0	0	0	0	0	22
		Dec.	221	8	0	0	1	0	230
	Immature	Oct.	0	4	8	8	3	0	23
		Dec.	1	6	35	48	23	6	119
Females	Adult	Oct.	18[2]	0	0	0	0	0	18
		Dec.	164	5	1	0	0	0	170
	Immature	Oct.	0	5	2	2	3	0	12
		Dec.	2	12	39	26	24	4	107
Total									701

[1] A few specimens were slightly damaged and all characters could not be inspected on every wing.
[2] New tertials growing in October were not considered to be an immature character.

be expected only by first becoming familiar with the characters through a study of known-age material.

KEY TO SEX OF MALLARD WINGS

1. Scapulars (if present)
   a. Vermiculated ..... Male
   b. Not vermiculated 2
2. Most proximal underwing coverts
   a. Vermiculated ..... Male
   b. Not vermiculated 3
3. White bar anterior to the speculum
   a. Extends uninterrupted proximally at least partially over tertials ..... Female
   b. Does not extend uninterrupted over tertials ..... Male

KEY TO AGE OF MALE MALLARD WINGS

1. Tertial coverts (one or more of five most proximal coverts)
   a. Any of the following:
      (1) Much frayed.
      (2) Faded.
      (3) Noticeably narrow and dull colored ..... Immature
   b. Not as above 2
2. Tertials
   a. Any of the following:
      (1) "Pearly" color lacking.
      (2) Much frayed at tips.
      (3) Much faded.
      (4) Sprouting new tertial *after* December 1 ..... Immature
   b. Not as above 3
3. Primary coverts (tip of *inner web* on four most distal coverts)
   a. "Conspicuously" to "minutely" edged light ..... Immature
   b. No light edging present 4
4. Middle coverts
   a. Any of the following:
      (1) Edged (usually very finely) with light brown.
      (2) Appear small; narrow to a rounded tip; somewhat trapezoidal.
      (3) Edges much frayed ..... Immature
   b. Lack light brown edge; may be "washed" with dark rufus; appear large; tip a smoothly rounded arc; edges smooth ..... Adult

KEY TO AGE OF FEMALE MALLARD WINGS

1. Tertial coverts (one or more of five most proximal coverts)
   a. Any of the following:
      (1) Much frayed.
      (2) Faded.
      (3) Noticeably narrow.
      (4) No white edging on two most posterior coverts ..... Immature
   b. Not as above 2
2. Tertials
   a. Any of the following:
      (1) Much frayed tips.
      (2) Much faded ..... Immature
   b. Not as above 3
3. Primary coverts (tip of *inner web* on four most distal coverts)
   a. "Conspicuously" light edged ..... Immature
   b. "Minutely" light edged or unedged 4
4. Middle coverts
   a. Any of the following:
      (1) Appear small; narrow to a rounded tip, somewhat trapezoidal.
      (2) Edges much frayed ..... Immature
   b. Appear large; tips are smoothly rounded arcs; edges smooth ..... Adult

ACCURACY OF THE TECHNIQUE

To test the reliability of the method, we used the series of 1,194 mallard wings collected in Missouri, Arkansas, and Louisiana from birds that had been examined cloacally. These wings were marked only by numbers before shipment to Patuxent where age and sex determinations were made solely from the wings. These two examinations are compared in Table 4. A total of 5.4 percent were classified differently by independent cloacal and wing examinations. If compensating errors are subtracted, only 1.8 percent remain incorrectly classified. Some errors probably were the result of mistakes made during the cloacal examinations.

Several months after this initial test, and following some refinement in techniques, Carney re-examined 461 of these wings.

TABLE 4.—COMPARISON OF SEX AND AGE DATA FROM INDEPENDENT CLOACAL AND WING EXAMINATIONS OF 1,194 MALLARDS

Sex	Age	Examination	Number Recorded	Percent of Total
Male	Adult	Cloacal	399	33.4
		Wing	404	33.8
	Immature	Cloacal	253	21.2
		Wing	243	20.4
Female	Adult	Cloacal	329	27.6
		Wing	328	27.5
	Immature	Cloacal	213	17.8
		Wing	219	18.3

Each wing was examined for approximately 20 seconds and no reverification was made. The classification of 5.0 percent differed from that obtained by cloacal determinations. Close re-examination of the discrepant wings revealed that: 2.2 percent were obvious errors that could have been corrected by reverification; 1.5 percent probably were due to faulty cloacal examination; and 1.3 percent were immature males that were classified as immature females. Thus, the potential accuracy agrees well with that shown in Table 3.

To determine how easily the technique could be learned by workers unfamiliar with the differences among mallard wings, a biologist at Patuxent was given 3 hours of instruction and allowed to practice making age and sex determinations for 5 hours. Then he was given 194 wings that he had not seen previously. More than one-half of these were from adults. The learning biologist classified 8.8 percent differently from the results of cloacal determinations, and his mistakes consisted almost entirely of calling adults immatures. The nature of these errors was called to his attention and he was tested on an additional 100 wings. This time 8.0 percent were incorrectly identified, but most of the errors resulted from calling immatures adults. We believe that although these tests were quite limited, they may indicate an unconscious tendency for a worker to bias age determinations toward what he believes are logical or true ratios. It is apparent that maximum accuracy will not be attained without considerable study of known-age material.

DISCUSSION

If age and sex ratios of shot birds could be determined from a representative sample of wings, much could be learned. The species composition of the kill could be determined for various areas and times throughout the season, and the distribution of the kill by species, age, and sex could be determined both geographically and chronologically. The implications of mortality-rate estimates computed from band recoveries would become much more meaningful if production-rate estimates also were available. Productivity data could serve to check the reliability of the aerial production survey which must be concluded prior to completion of the hatching period so that data will be available for developing hunting regulations. The complex of factors that affect production, such as changes in water conditions or phenology of the season, could be studied.

Seasonal population indices could be estimated by using data obtained from wing collections in conjunction with data from other sources. For example, if a representative sample of a particular species is banded on the wintering grounds, a population index could be obtained from information gathered during the following hunting season. Age ratios in a wing collection, total kill estimates from a mail kill survey, and total recoveries of the winter-banded birds reported to the Banding Office, could be used in the following formula:

$$\text{Winter population index} = \frac{(\text{total kill} \times \%\ \text{of Ad.})\ \text{no. of birds banded}}{\text{no. bands reported}}$$

The method is similar to the one suggested by Lincoln (1930). The estimate would relate to the population at the time of the winter banding. The number banded and the number of bands reported would refer only to the previous winter's banding. Because all the banded population would be adults during the hunting season, the banded-unbanded ratio of adults is required. This is obtained by multiplying the total kill by the percent that are adult as determined by the wing collection. To obtain an estimate of the actual population rather than an index, the number of banded birds reported would have to be corrected for the failure of hunters to report all bands that they take.

A possible method for measuring preseason populations would be to compute the banded-unbanded ratio directly from the sample of wings as follows:

$$\text{Preseason population} = \frac{(\text{no. birds banded}) \text{ wings in sample}}{\text{bands in sample}}$$

This method assumes that, if they are properly advised, respondents to a wing-collection survey would report virtually all the banded birds represented by the wings mailed. The number of birds banded and the number of bands in sample would refer only to the preseason banding. Because the adult male, adult female, and immature segments of the population would have to be computed separately, this method would require an active banding program and a large-scale wing collection. For example, let us assume that 48,000 mallards (0.4 percent of an estimated continental population of 12,000,000 having a ratio of 2 immatures per adult) can be banded prior to the hunting season. The true ratio of banded to unbanded immatures could then be estimated with an error (twice the standard error) of approximately 30 percent at the 0.95 confidence level from a sample of 30,000 mallard wings. This appears to be feasible because, in 1959 under a rather limited program, 19,356 mallards were banded on or near the breeding grounds prior to the opening of the waterfowl hunting seasons in Canada and the United States.

Another potential use of wing-collection data would be to obtain indices of the size of kill of each species in various parts of the United States. This would serve to verify the findings of the Waterfowl Hunters' Mail Questionnaire, which relies upon the hunters' identification of species. The following formula could be used:

$$\text{Kill index} = \frac{(\text{total duck stamps}) \text{ wings in sample}}{\text{hunters in sample}}$$

In order for this procedure to yield a valid index, it would be necessary for the wings received to represent equal proportions of the actual kill in all the sample areas, or for the differences in these proportions to be known so that the areas could be made comparable.

There are many problems that must be solved before species composition, age ratios, and sex ratios in a collection of wings can be transposed into composition and ratios in the population. Because of differences in wariness, migrational habits, or hunter selectivity, some age, sex, and species groups are more vulnerable to the gun than others. Comparison of band-recovery rates of flying birds banded prior to the hunting season could be used to evaluate this bias and to correct ratios when it is desirable to relate the information from wing collections to the population rather than to the kill.

There also are problems relating to the response rates of the hunters sampled in wing surveys. At present, we do not know if the wings received would represent the same fraction of the hunting kill at all times during the season or in all areas being sampled. Additional pilot studies used in conjunction with the analysis of band-recovery data or additional hunter-kill surveys might provide a means for correcting any bias of this nature that may be present.

Finally, methods of age and sex determination are yet to be perfected for other species of ducks. However, many of the characters found to be useful for separating mallard wings are present on other species, particularly the dabbling ducks (Anatinae). Further studies of wing plumage undoubtedly will lead to the development of techniques for determining age and sex from wings for most of the more common ducks.

SUMMARY

This paper describes characters on the wing plumage of the mallard that indicate age and sex. A key outlines a logical order in which to check age and sex characters on wings. This method was tested and found to be more than 95 percent reliable, although it was found that considerable practice and training with known-age specimens was required to achieve this level of accuracy.

The implications of this technique and the sampling procedure it permits are discussed. Wing collections could provide information on production, and, if coupled

with a banding program, could permit seasonal population estimates to be calculated. In addition, representative samples of wings would provide data to check the reliability of several other waterfowl surveys.

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MOVEMENT PATTERNS OF BRUSH RABBITS IN NORTHWESTERN CALIFORNIA

Paul W. Shields

United States Forest Service, Fresno, California

The brush rabbit (*Sylvilagus bachmani*) is one of the most abundant upland game animals in California. This species has been neglected as a potential game resource, possibly because of lack in information concerning its habitat requirements and the factors determining its numbers.

To obtain information on brush rabbit ecology, this study was begun in October 1956 and continued 16 months until February 1958.

Raymond F. Dasmann and R. E. Genelly of the Humboldt State College Division of Natural Resources gave advice and assistance throughout the study and aided in preparation of the manuscript. Daniel H. Brant and E. O. Salo of Humboldt State College helped in various phases of the study. Personnel of the California Department of Fish and Game were cooperative throughout the study.

STUDY AREA

The study was conducted on the North Spit of Humboldt Bay, Humboldt County, California. The sand spit, formed by wind and tidal action, is about ½ mile wide and 10 miles long and is bordered on the east by Humboldt Bay and on the west by the Pacific Ocean. The southern end is low and covered by low-growing vegetation, whereas the northern portion is higher with wooded dunes.

The study was confined to an area of approximately 12.4 acres on the southeastern end of the spit (Fig. 1). The largest vegetation on the area consists of bush lupine (*Lupinus arboreus*) growing in dense,

FIG. 1. Aerial view of study area on North Spit looking westward.

unevenly spaced patches separated by open grassland. Almost all of the area, in contrast to much of the rest of the spit, is vegetated to some degree with very little sand left bare. The study area is flat, bordered on the west by a stabilized dune ridge and on the east by Humboldt Bay.

The climate in the area is characterized by a relatively high humidity during the entire year. A wet season extends from October through April with approximately 33 of the normal 36 inches of precipitation falling during this period. During the dry season, which extends from May through September, there are frequent fogs or low cloudiness. Temperatures are moderate throughout the year, ranging from 36° to 75°F. The daily average temperature range during summer months is about 9°F. and during winter months 13°F.

METHODS OF STUDY

Information on brush rabbit mobility was obtained by live-trapping, marking and subsequent recapture; by noting the location of marked animals which were later shot or found dead; and through direct observation of free living animals.

Trapping

Sixty permanent trapping stations were established on the edges of dense lupine thickets and the stations were marked by numbered wooden stakes. Box traps were placed within a 3-foot radius of the station marker and usually pushed back beneath the protective lupine with the entrance flush with the lupine edge. A few stations were inside the lupine thickets.

The traps were sensitive enough to capture young animals which weighed as little as 87 grams, but were not sensitive enough to be sprung by birds or mice. Of several baits tried, including lettuce, apples and carrots, only rolled or whole barley and wheat proved effective. Whole barley was the principal bait used. Traps were usually checked during morning hours, but occasionally during the afternoon.

Marking

The right ear of animals trapped for the

first time was tattooed (Schwartz, 1941); and a small aluminum rivet (Tyndale-Biscoe, 1953) with the same number as the tattoo was placed in the left ear, along with a single, colored celluloid disc. Discs of blue, red, yellow, white, and orange were used; white, orange and yellow were easiest to see when the animals were later observed. These ear discs sometimes caused necrosis and consequent sloughing of the tissue, with the result that discs either dropped out or had to be removed from numerous animals. For example, discs had to be removed from two animals 47 days after they had been tagged because the metal washer was cutting into the ear. A few discs were found where they had been lost by rabbits. In each case where the disc was lost or removed, the ear healed satisfactorily. On the other hand, discs were still present on some rabbits with no signs of infection as long as 6 months after marking.

Normally brush rabbits were easily trapped, but occasionally some were reluctant to enter the traps. Haugen (1942) noticed similar behavior in cottontails in Michigan. While feeding, rabbits often used the traps as aids in reaching the higher lupine stems and leaves. At other times, tracks in the sand or fresh diggings beneath the trap indicated that rabbits had visited the station but did not enter. Sometimes a slight change in the location of the trap would cause these unproductive stations to begin taking rabbits regularly.

TRAPPING RESULTS

A total of 2,036 trap nights resulted in the capture of 148 brush rabbits; there were 737 recaptures. Since trapping effort varied greatly from month to month, it was necessary to use capture per trap night (Table 1) as a measure of relative success during the entire trapping period.

The marked decline in trapping success during April and May perhaps reflects the combined effect of heightened breeding activity and an abundance of food. Success increased in June and continued through August after which the traps were removed.

TABLE 1.—SUMMARY OF TRAPPING ON THE NORTH SPIT OF HUMBOLDT BAY, HUMBOLDT COUNTY, CALIFORNIA, DURING 1957

Month	Trap Nights	Animals Captured	Captures Per Trap Night
February	177	77	0.44
March	414	195	0.47
April	261	80	0.31
May	449	139	0.31
June	283	113	0.40
July	220	121	0.55
August	232	160	0.69
Totals	2036	885	
Average			0.43

This is similar to what Fitch (1947) found working with Audubon cottontails in the San Joaquin Valley. This greater susceptibility to trapping during summer months is possibly caused by drying of grasses and forbs, with consequent loss of palatability. Trapping success may also be affected by the annual increment of juveniles in the population, but this is probably of minor importance. Young began appearing in traps in early April. Since many young were taken within a few days after leaving the nest, this affected trapping results as much in earlier months as during the summer.

MOVEMENT PATTERNS

Animals were separated into the following groups: adult males; adult females; juvenile males; juvenile females. Captures and recaptures were mapped with the majority of animals observed at 3 to 12 points. The greatest distance across the known range served as the range diameter. Some animals undoubtedly traveled over larger areas than trapping records indicated; thus this figure for home range should be regarded as a minimal estimate. Of the 36 marked animals whose kill locations were noted, 23 were shot inside the area of their home range as indicated by trapping. Seven animals were collected that exhibited exceptional movement patterns. These will be discussed later.

Adults

Table 2 gives the summarized movement

TABLE 2.—MOVEMENT DATA FOR BRUSH RABBITS IN 1957

	Number of Individuals	Number of Captures			Range Diameter (in feet)		
		Maximum	Minimum	Mean	Maximum	Minimum	Mean
Adult males	32	27	2	9	556	50	278
Adult females	31	24	2	9	569	38	149
Juvenile males	17	19	2	6	325	25	131
Juvenile females	22	26	2	5	500	31	191

data. The average range diameter for adult males was 278 feet, significantly larger than the figure of 149 feet for adult females. In the San Francisco Bay area, brush rabbits have a range diameter of 290 ± 31 feet for males and 169 ± 22 feet for females (Connell, 1954). Fig. 2 shows typical home ranges for both sexes of adults. It should be recalled that trapping was conducted from mid-February through the end of August and that the breeding season for both sexes extends from about the onset of trapping until the end of June. Connell (1954) found that male ranges increased during the breeding season while those of the female decreased in size. Apparently males are seeking mates and roaming over larger areas. Among females, the decline in range diameter as shown by Connell is probably connected with the care of young. It is possible that the difference in movement patterns of the two sexes would not have been so great in the present study if trapping had been conducted throughout the entire year. It is assumed that both sexes were equally vulnerable to trapping.

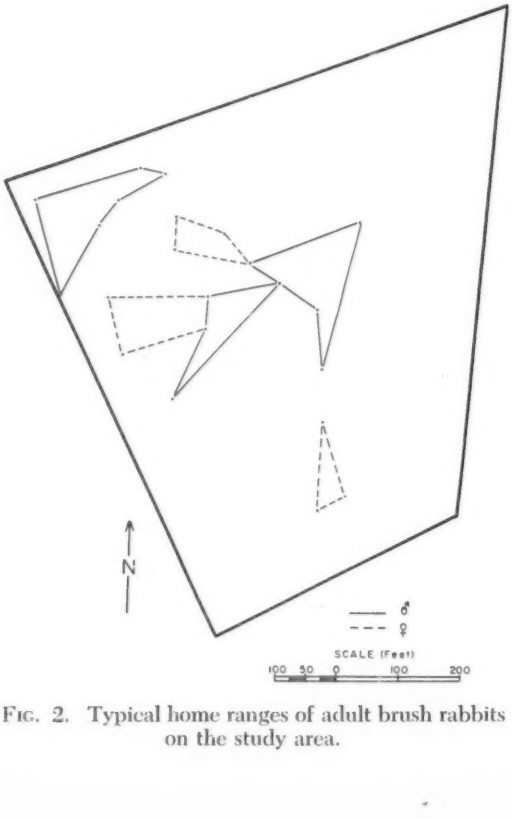

FIG. 2. Typical home ranges of adult brush rabbits on the study area.

The distance traveled from the point of original capture was computed for adults of both sexes. It is recognized that trap spacing can affect these movement data. Traps were set only in lupine and lupine-grassland areas; no trapping stations were in open grassland. As a consequence, many traps were relatively close together. The average distance between traps was approximately 100 feet.

Table 3 shows that 174 or 67 percent of the total female captures occurred at less than 100 feet from the original trapping point, while only 24 percent of the male captures were in this group. If the distance traveled is extended to 300 feet, 96 percent of the female and 75 percent of all male captures are included. Although many males were trapped farther than 400 feet from the original capture point, only one female (number 116) was captured at such a distance. Her movement pattern will be discussed later.

When movements of all adults were plotted, it was found that ranges overlapped indiscriminately. When both sexes were compared, it was found that no animal occupied a separate, isolated home range. However, there was much less overlapping in ranges of females than of males. Connell (1954) detected a similar situation in the

TABLE 3.—DISTANCES (IN FEET) BRUSH RABBITS MOVED FROM POINTS OF ORIGINAL CAPTURE TO SUCCESSIVE CAPTURES

	0–100	101–200	201–300	301–400	401–500	501–600	Total of Each Sex
Male	65	85	52	25	31	8	266
Female	174	51	23	10	0	1	259
Total for each distance	239	136	75	35	31	9	525

Berkeley hills. Fourteen females in the present study enjoyed separate home ranges; no males had an isolated area.

Juveniles

The home range for juvenile females was calculated to be 191 feet as compared with a figure of 131 feet for juvenile males. However, this difference was not significant at the 95 percent confidence level.

Exceptional Movements

Of the seven rabbits showing exceptional movement patterns, four were juveniles and three were adults; of the four juveniles, three were males. These animals represented 6 and 4 percent, respectively, of the total marked juvenile and adult population.

Rabbit 64 was observed approximately 231 feet north of the nearest station at which it had been captured. This was outside the study area and is possibly explained as a breeding foray since this buck was later trapped and eventually shot in the study area.

Rabbit 39, an adult, was captured 18 times during the study, the range diameter being 193 feet. It was shot 550 feet from the nearest capture point. Such a movement may have been due to population pressure or a seasonal shift in home range. Ralph McCormick of the California Department of Fish and Game has observed that brush rabbits, chased by beagles, circle time after time in approximately the same area. He states that it is almost impossible to drive them out of thick cover with the aid of dogs.

Animal 116 was the only female to be trapped farther than 400 feet from the original point of capture. Between June 26 and July 20, 1957, she moved 569 feet. Following the second capture, this animal was taken an additional nine times in another station between the two capture points but 425 feet to the south. She remained around this station until trapping was suspended on August 30, 1957.

The reason for this apparently extensive movement within the study area, followed by settling down in a small area, is unknown. Immigration seems likely for two reasons: (1) the animal was first trapped some 4½ months after the study began, whereas it is believed that all adults had been captured during the first 2 months; and (2) the animal showed an erratic movement pattern for some 3 weeks after the first trapping, and then became established in an area in which she remained throughout the rest of the trapping period.

The distances traveled by emigrating juveniles varied from 562 feet to 1,156 feet.

High population density is the most probable reason for movement of animals from the area, although brush rabbits seem to tolerate crowding. Of 117 collected within a ½-mile radius of the study area, only 5 (4 percent) were marked, a fact which indicate that only a relatively few animals move out of the area in which they are born.

Investigators have reported cases of emigration in the cottontail rabbit. Dalke and Sime (1938) found four rabbits from 1 to 2.4 miles from where they were marked as juveniles. Allen (1939) mentions one juvenile recovered 7 months after being marked three-fourths of a mile from the recovery point. Hickie (1940) found three animals which had moved ½, ¾ and 16 miles, re-

spectively. Schwartz (1941) lists 10 rabbits (5 adults) which moved from 1,322 to 3,542 feet.

Factors Influencing Movements

Brush rabbit mobility is affected by cover, food supply, breeding season, population pressure, and possibly weather.

Cover and food supply are extremely important to both daily and seasonal movements. Since it is impossible to divorce the two factors, they will be discussed together. Bush lupine, the major escape cover used by brush rabbits on the study area, is also the staple food. Brush rabbits are generally found within a few yards of lupine cover throughout the year. Exceptions occur during the relatively dry summer months when animals are observed some distance from lupine eating bur clover (*Medicago hispida*), which they relish while it is growing.

The onset of the breeding season causes an increase in mobility of male brush rabbits and a decrease in the ranges of females (Connell, 1954). Some males make long movements apparently in search of mates. Females tend to become more sedentary during the breeding season, probably because of parturition and subsequent care of young.

Population pressure is the most likely cause of emigration of animals, particularly juveniles, from an area. When the population is high, as on some areas of the North Spit, considerable intraspecific strife can be expected. Some individuals, principally juveniles unable to contend with these pressures, are forced to emigrate to less desirable areas.

Although weather has little influence on movement, adverse conditions such as dense fog, high winds, and rain do curtail brush rabbit activity. Few, if any, animals are seen under such conditions. However, it was found that trapping success was not unduly affected by these conditions. Trapping was frequently very productive during adverse weather of short duration and during storms lasting several days. Conversely, at times when the weather was favorable, trapping success was low.

SUMMARY

A brush rabbit population was intensively studied over a 16-month period in northwestern California. A total of 148 animals were captured, marked and released. Subsequent observations revealed that the adult male range diameter was 278 feet, significantly larger than the 149 feet recorded for females.

Sixty-seven percent of females recaptured were taken less than 100 feet and 96 percent were taken less than 300 feet from the original trapping points. The respective percentages for males were 24 and 75. Many males, but only one female, were taken further than 400 feet from the original capture points.

Seven rabbits exhibited exceptional movement patterns. Of these, five were males, four were juveniles. Six percent of the marked juveniles and a calculated 4 percent of the adults emigrated. Distances traveled by emigrating juveniles ranged from 562 to 1,156 feet.

Brush rabbit mobility is affected by cover and food supply, breeding season, population density and possibly weather.

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DEER–FOREST HABITAT RELATIONSHIPS IN NORTH ARKANSAS[1]

Lowell K. Halls and Hewlette S. Crawford, Jr.

Southern Forest Experiment Station, Forest Service, U. S. Department of Agriculture,
New Orleans, Louisiana

This paper gives an account of a deer population buildup and decline on the Sylamore District of the Ozark National Forest in northern Arkansas. The upland hardwood forests of the Ozarks can support good herds of white-tailed deer. During the early years of a timber rotation, food and cover are plentiful and deer increase rapidly. If deer are uncontrolled, they may become too numerous. When this happens, food plants are damaged or destroyed, forage production is reduced, and deer decline. Recovery of the food plants and the herd is slow and may be curtailed with the formation of a dense tree canopy which gradually moves beyond the reach of deer and shades out the understory.

Buildup and Decline of the Deer Herd

In 1923, there were approximately 25 deer on the 173,000-acre Sylamore District. In 1926, two game refuges, the Livingston and Barkshed, were established and the entire forest closed to hunting (Donaldson, *et al.*, 1951). Deer numbers increased to about 350 by 1932, when the forest, exclusive of the refuges, was opened for hunting with dogs. Legal kill that year was six deer. Deer numbers increased steadily through 1938, but then rose sharply the next few years. In 1938, the entire Sylamore District was closed to hunting with dogs. By 1944, there were an estimated 3,700 deer of which 740 were removed, 421 bucks by legal kill and 319 bucks and does by trapping. The following two years, 800 to 900 were removed by trapping and hunting. The trapped deer were used to restock other forest areas in the State.

The tremendous increase in deer numbers came when the young timber stands were developing. Predator control, elimination of dog hunting, hunting of bucks only, protection afforded by the refuges, and favorable food conditions brought about by timber stand improvement practices all contributed to expanding the population.

Two main events developed concurrently: (1) deer increased beyond the productive capacity of the range, and as a result they severely damaged or destroyed browse plants; (2) some plants grew beyond the reach of the deer and others were crowded out by the developing trees.

A severe imbalance between deer and forage was evident by 1945. Forage utilization was extremely heavy (Table 1). Preferred plants (Donaldson, *et al.*, 1951) were being browsed excessively. All available growth of wild grape was eaten and, as a result of heavy winter browsing, young cedars had a hedged appearance. Less desirable plants such as oak and hickory also showed signs of overuse. Even where deer concentration was lightest, browse lines were forming. The contrast between the amount of forage in deer-proof exclosures and open range was striking (Holder, 1951). Because the plants had been closely utilized for several years, their vigor and productivity were low.

The first indication that deer were decreasing was noted in 1946 when legal kills dropped to approximately 300, or about 120 less than in the peak year of 1944. Cessation of the trapping program in 1948 failed to stop the decline, and by 1951 the deer were

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[1] Cooperative investigations between Arkansas Game and Fish Commission, University of Arkansas, Ozark National Forest, and Southern Forest Experiment Station.

Assistance in carrying out this study was received from Dexter Thomas and Harold Alexander, Arkansas Game and Fish Commission; F. M. Meade, University of Arkansas; D. M. Moore, Arkansas A. & M. College; Odell Julander, Intermountain Forest and Range Experiment Station; and H. D. Burke, Northeastern Forest Experiment Station.

TABLE 1.—SEASONAL UTILIZATION[1] OF FORAGE (IN PERCENT) UNDER HEAVY CONCENTRATIONS OF DEER ON THE SYLAMORE FOREST, 1945

Species[2]	AVAILABLE FORAGE REMOVED		
	Spring	Summer	Winter
TREES			
Hickory (*Carya* spp.)	59	40	—
Eastern redbud (*Cercis canadensis*)	—	80	—
Flowering dogwood (*Cornus florida*)	25	45	12
Eastern redcedar (*Juniperus virginiana*)	—	—	75
Blackgum (*Nyssa sylvatica*)	—	37	—
White oak (*Quercus alba*)	26	47	45
Black oak (*Quercus velutina*)	5	10	—
Black locust (*Robinia pseudoacacia*)	—	82	—
Sassafras (*Sassafras albidum*)	5	38	5
SHRUBS AND VINES			
Virginia creeper (*Parthenocissus quinquefolia*)	32	—	—
Fragrant sumac (*Rhus aromatica*)	7	21	—
Smooth sumac (*Rhus glabra*)	—	20	—
Blackberry (*Rubus* spp.)	5	47	—
Greenbrier (*Smilax* spp.)	62	69	10
Deerberry (*Vaccinium stamineum*)	3	43	37
Low blueberry (*Vaccinium vacillans*)	—	25	15
Southern blackhaw (*Viburnum rufidulum*)	—	32	—
Wildgrape (*Vitis* spp.)	72	99	—
FORBS			
Pussytoes (*Antennaria plantaginifolia*)	—	5	—
Thistle (*Cirsium* spp.)	—	42	—
Ticktrefoil (*Desmodium* spp.)	16	50	—
Fleabane (*Erigeron* spp.)	—	15	—
Sunflower (*Helianthus* spp.)	5	20	—
Wild lettuce (*Lactuca* spp.)	—	70	—
Lespedeza (*Lespedeza* spp.)	—	44	—
Mint (*Mentha* spp.)	10	—	—
Horsemint (*Monarda* spp.)	—	67	—
Dock (*Rumex* spp.)	—	25	—
Crownbeard (*Verbesina* spp.)	—	35	—
GRASSES AND GRASSLIKE PLANTS			
Sedge (*Carex* spp.)	—	3	10
Oatgrass (*Danthonia* spp.)	—	3	—
Panicum (*Panicum* spp.)	—	25	—

[1] Utilization was estimated according to procedures described by Campbell and Cassady (1955).
[2] Scientific and common plant names are those of Fernald (1950) and Little (1953).

so scarce that the legal kill was only 108. Further evidence of an unhealthy herd was noted in the spring of 1950, when 30 deer were found dead from causes other than hunting (Alexander, 1954). Since 1951, the legal kills have averaged nearly 200, evidence that populations are still low but increasing slowly.

VEGETATION CHANGES FOLLOWING HEAVY DEER CONCENTRATION

In the spring of 1945, the three major timber–browse types of the Barkshed and Livingston refuges—oak–hickory–grape–greenbrier, shortleaf pine–oak–blueberry, and eastern redcedar–hardwood–greenbrier—were selected for a study of vegetational responses. Livestock and deer were excluded from a series of three 0.1-acre plots in each type. Similar plots remained unprotected. Data taken from 1947 to 1957 show changes in vegetation that occurred under complete protection and a reduced intensity of use which began in 1946. Weight of browse and

TABLE 2.—CHANGES IN VEGETATIVE PRODUCTION[1] IN POUNDS PER ACRE, GREEN WEIGHT, 1947 TO 1956

Class of Vegetation	Exclosures[2]			Unprotected Plots		
	1947	1951	1956	1947	1951	1956
TREE FOLIAGE AND TWIGS						
Preferred	26	41	59	26	48	125
Non-preferred	100	209	259	88	141	207
	126	250	318	114	189	332
SHRUBS AND VINES						
Preferred	149	244	325	120	171	244
Non-preferred	159	126	191	53	100	112
	308	370	516	173	271	356
FORBS						
Preferred	54	113	92	35	68	49
Non-preferred	329	206	4	61	58	83
	383	319	96	96	126	132
GRASSES						
Preferred	0	20	24	0	13	52
Non-preferred	24	78	81	26	59	37
	24	98	105	26	72	89
TOTAL	841	1,037	1,035	409	658	909

[1] Consists of the total annual growth of forbs and grasses and the annual leaf and twig growth of trees, shrubs, and vines up to a height of 5 feet.

[2] Deer and livestock were excluded from these plots in the spring of 1945.

herbage was estimated (Pechanec and Pickford, 1937) to a height of 5 feet on ten 3.1-foot square plots inside and outside each exclosure.

Vegetation responded immediately to relief from heavy use. In 1947, the yields on plots that had been protected for three growing seasons were double those of unprotected plots (Table 2). Likewise, with the decrease in intensity of use after 1946, vegetative growth, even though low, increased on the unprotected plots. This increase, an indication of range recovery, started during the years when deer numbers were least. Shrubs, vines, and forbs made the most immediate increases; tree foliage and twig growth responded less quickly.

Non-preferred browse plants increased in about the same proportion as preferred, thus preventing the preferred from regaining their former relative position of abundance. As noted by Leopold, *et al.* (1947), under heavy deer pressure the composition of the flora tends to shift in an unfavorable direction. Thus, a slackening or elimination of browsing will not completely rectify past misuse.

Timber types, age class, and crown closure, along with grazing, influenced the production and availability of various sources of forage.

Trees.—Some plots within the oak–hickory type showed the expected increase in vegetative growth when deer numbers declined. The effect was only temporary because by 1957 most of the tree foliage was above 5 feet and hence out of reach for deer. (Fig. 1).

Many areas in the cedar–greenbrier type had a low tree canopy in 1945 and produced abundant forage despite heavy use. The plants recovered with protection, and in 1956 forage production was 1,525 pounds per acre—high yields considering that in this type also most trees had developed until the bulk of foliage was above 5 feet. Main species were eastern redcedar, hackberry (*Celtis occidentalis*), black oak, redbud,

FIG. 1. *Top.*—This stand of white oak, black oak, hickory, and winged elm (*Ulmus alata*) had a definite browse line in 1945. *Bottom.*—After more than a decade of light use, forage was still sparse because most tree foliage had grown beyond reach of deer.

FIG. 2. *Top.*—A long period of extremely close use had severely reduced browse production in 1945. *Bottom.*—Even though use was lightened, the hackberry in right foreground was dead by 1956. The fairly close canopy of eastern redcedar, hackberry, chinkapin oak (*Quercus muehlenbergii*), winged elm, and redbud limited the understory growth.

FIG. 3. *Top.*—Vegetative production beneath a tall overstory of red oak (*Quercus falcata*), white oak, and shortleaf pine (*Pinus echinata*) was 254 pounds per acre in 1947. *Middle and Bottom.*—A timber harvest in 1950, followed by timber stand improvement, permitted the development of a low cover of black locust, black and post oak (*Quercus stellata*), sassafras, blueberry (*Vaccinium* spp.), lespedeza, and ticktrefoil. In 1956, production was 1,115 pounds per acre.

FIG. 4. *Top.*—This photo illustrates the high forage potential of the upland pine–oak type during the formative years of a timber rotation. Even though browsing was heavy, production in 1947 was 1,040 pounds per acre. *Bottom.*—The dense overstory of white and chinkapin oak, hickory, and red maple (*Acer rubrum*) had reduced forage to 540 pounds per acre by 1956.

white ash (*Fraxinus americana*), greenbriers, fragrant sumac, and rattan vine (*Berchemia scandens*).

On other plots in the same forage type, but on thinner soils, heavy browsing killed many young trees and shrubs. Even though yields increased slightly when deer numbers fell off, the long-time effects of overuse and the tree overstory restricted production (Fig. 2).

Plots in the pine–oak type further illustrate the relationship between forage and timber. Vegetation production on an area dominated by a tall dense overstory was greatly increased by a timber harvest and timber stand improvement practices (Fig. 3). Similar responses have been noted by Ruff (1938) and Martin, *et al.* (1955).

In another area of the oak–pine type, a low canopy of small, heavily grazed hardwoods produced abundant vegetation in 1947. By 1955 tree foliage had moved above 5 feet and forage had lessened even though browsing was light (Fig. 4).

Shrubs and vines—These groups of plants normally contribute the greatest portion of deer forage. Their abundance is largely influenced by grazing pressure (Dalke and Spencer, 1944) and timber overstory. On some plots where the overstory was light or absent, palatable vine growth was severely restricted by heavy browsing in 1945, but increased under protection to 1,900 pounds per acre in 1956. This appeared to be the upper limit of vine production because as young trees developed they allowed the vines to climb above the reach of deer. The vines were chiefly greenbrier and grape. Where overstory was dense, few shrubs were available to deer; improvement of the habitat for deer would probably require opening the timber stand.

Areas with medium to dense high canopies permitted a fair undergrowth of vines and shrubs. Heavy browsing reduced the vigor and killed many of the palatable species. Under protection, there was a gradual increase in shrub and vine yields but a large portion consisted of non-preferred plants.

Forbs and grasses.—Although the use of forbs is often obscure, these plants are an important source of deer food in the Ozarks (Dunkeson, 1955). Under protection, forbs recovered rapidly from overgrazing, except where canopies were dense. Generally they achieved greatest importance in the cedar-greenbrier type. Here, the forbs most productive were legumes, sunflowers, and pussytoes.

Grasses also were of greatest importance in the cedar–greenbrier type. They were scarce in other types and their production was influenced little by deer grazing.

SUMMARY

In a favorable habitat, deer herds increased rapidly in the Arkansas Ozarks and soon exceeded the range's carrying capacity. Continued overbrowsing seriously reduced forage and brought about the decline of the herd. Preferred plants suffered most, and a recovering range included many non-preferred plants.

The development and structure of the timber stand also affected habitat potential. In the reproduction phase of the forest, food was plentiful. As stands increased in size and density, they excluded most of the understory, but forage became more plentiful after a timber harvest. Abused habitat seeemed to recover about as rapidly under light to moderate use as under complete protection.

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PRODUCTION OF GAME BIRD FOODS IN MISSOURI[1]

Leroy J. Korschgen

Missouri Conservation Commission, Columbia, Missouri

This study was conducted to learn how much food is available on certain types of landscape in autumn to upland game, particularly quail, doves, and pheasants. Previous food habits analyses of numerous samples have shown the kinds and quantities of foods eaten by Missouri's game birds (Korschgen, 1948, 1952, 1958, 1959). Information was needed to show whether the principal foods were normally available in quantities adequate for current or increased populations. The present investigation covered an extensive area, so that general averages of the most important foods could be obtained.

REVIEW OF LITERATURE

Published information on seed production and availability for game bird food is scanty. Studies with other objectives, nevertheless, reveal pertinent and useful information. Brenchley and Warington (1930) estimated the number of viable weed seeds, as shown by the seedlings germinating in the soil. Dalke (1935), in Michigan, was among the first to report measured quantities of game bird foods. Amounts were interpreted as carrying capacity for pheasants. Allen (1938), in southern Michigan, found that during winter much of the natural food supply was taken by flocks of songbirds, and by mice. He concluded that the prairie deer mouse was the most important competitor of ground-feeding birds.

Leedy's studies in Ohio (1939) showed quantities of waste grain and weed seeds per acre in cultivated fields. Poundages were determined by cutting all plants of a weed species on square-rod plots, then threshing, cleaning, and weighing the seed. Baumgras (1943), in Michigan, clipped meter-square quadrats each winter month and measured the seeds on stems. Competition between game birds, songbirds, and rodents for weed seeds was reported to be of minor importance—a conclusion varying from that of Allen (1938). Bishop and Spinner (1946), studying quantities of pheasant foods in Connecticut cornfields, located 10 mil-acre plots in each of 20 fields during autumn. They based calculations upon the average weight of seed per stem in 100 stem samples and a count of all stems in the plots. The average weight of seed per acre on "good" soils was twice that on "fair."

Haugen and Fitch (1955) reported on seasonal availability of bush lespedeza and partridge pea seeds by analysis of 1-sq.-ft. samples of litter down to bare soil, collected periodically from selected plots. Davison, *et al.* (1955), in summarizing seven methods

[1] A contribution from Pittman-Robertson Project, Missouri 13-R.

of evaluating wildlife foods, concluded that ground sampling was practical for determining yield and availability. Dickerson (1956) used both seed traps and ground samples to study climatic influences on availability of shrub lespedeza seed to quail in Virginia and North Carolina. Durell (1956), in Kentucky, also studied shrub lespedeza seed production, rate of falling, and persistence on the ground; catch boxes indicated average production. Bookhout (1958) studied quantity of seeds produced, duration of availability, and relationship between availability of seeds and their consumption by bobwhites in southern Illinois.

TECHNIQUES

This study was begun during the fall of 1954 soon after the first killing frost. Sample areas in six counties—three in northern Missouri (Andrew, Daviess, Caldwell) and three in southern Missouri (Greene, Laclede, Dent)—were selected for study. The principal soil types were: Grundy, Shelby, and Summit soils in northern Missouri; Crawford, Lebanon, and Hanceville in southern Missouri. These represent both the best and the poorest agricultural lands in the State.

The study areas were upland sites previously established for Missouri Soil Sample Surveys (1943). The areas, approximately 15 square miles in size, were recommended by the University of Missouri, Department of Soils, as being typical of soil types. The soils are rated as follows by Krusekopf's (1945) fertility scale: Grundy, very good; Shelby and Summit, good; Crawford, medium; Lebanon and Hanceville, poor. (In this scale, categories are: very good, good, medium, inferior, and poor.)

Equipment for collecting soil samples consisted of a metal frame 2 in. deep, with an inside area of 1 sq. ft., sharpened to a cutting edge on the bottom by an outside bevel; aluminum scoop (modified sugar scoop giving a broad, flat cutting edge); a jackknife; 9-in. × 12-in. plastic bags; and data cards printed to show county, area, sample number, and field type. ("Field" or "field type" is used in a broad classification to designate a unit of land characterized by particular plants, whether open, cultivated, grassland, or woodland.)

Since previous studies of quail, dove, and pheasant food habits in Missouri showed that the bulk of their food was gleaned from corn, cane, small grain, and soybean fields, pasture, oak woodland, sassafras, and fallow and waste lands (Korschgen, 1948, 1952, 1958, 1959), these were the types sampled.

Soil samples were collected from fields within each soil type area, usually in the order of their being located. If the field showed abuse by livestock, burning, etc., another field of the same type was located for sampling. All samples were collected from November 15–24, 1954, and from November 15–December 6, 1955. The first sample in each field was taken near the border; subsequent samples were taken at approximately 50-yard intervals toward the center. At each site the metal frame was seated to include all vegetation on the square-foot area. Seeds on overhanging stems then were shattered onto the study plot. Interfering stems or roots were cut with a knife around the inside of the frame. Vegetation, litter, and topsoil to approximately ½-inch depth (quail and pheasants may scratch to this depth) were scooped into a plastic bag. Five samples usually were taken from each field and pertinent data included with each sample.

Samples were collected from the same six county areas at the end of the growing season in 1954 and 1955. Collections during the second year were from the same plant associations, but usually from different fields within the study areas, because of crop rotations.

In each analysis, the sample was placed in a 30-mesh-per-inch sieve and strongly flushed under the tap to remove most of the soil. The remaining material was dried, hand-crushed, and run through a small grain, seed, and bean cleaner to separate seeds from gravel, stems, and leaves. Final separation was done with scalpel and forceps, usually following a floating and decanting system with carbon tetrachloride.

TABLE 1.—AVERAGE NUMBER AND QUANTITY OF SEEDS PER UNIT AREA IN MISSOURI, 1954 AND 1955

Field Type	Number of Samples	Seeds per Square Foot		Pounds per Acre		
		Number	Vol. in cc.	Select	Nonselect	Total
Corn	63/50[1]	336/606	3.1/1.3	135/44	36/28	171/72
Machine-picked	39/5	389/10	4.1/2.3	201/159	31/tr.	232/159
Hand-picked	24/45	251/672	1.4/1.2	27/31	44/31	72/62
Cane	27/34	850/177	1.7/1.3	41/55	45/15	86/70
Small grain	53/62	1,737/764	3.2/3.9	118/63	60/81	178/144
Wheat	34/32	1,803/1,010	2.6/2.9	84/61	59/82	143/143
Oats	14/20	1,514/551	4.0/5.6	132/60	75/86	208/146
Rye	5/5	1,913/423	5.6/2.3	306/71	25/34	331/105
Barley	0/5	0/385	0/5.0	0/83	0/105	0/188
Soybean	41/0	375/0	1.8/0	94/0	21/0	115/0
Pasture	53/52	817/795	2.7/3.8	135/102	13/67	148/169
Fallow–waste	36/33	777/1,110	3.3/5.6	101/86	42/175	143/261
Woodland	30/53	69/57	1.2/0.7	16/30	44/6	60/37
Sassafras	0/45	0/88	0/0.5	0/12	0/12	0/24
Total or Average	303/329	741/513	2.5/2.6	102/55	37/52	139/107

[1] Numbers to left and right of line refer to northern and southern Missouri, respectively, throughout the table.

The clean, mature seeds were sorted according to kind, identified, counted, measured for volume, and weighed to the nearest ten-thousandth of a gram.

RESULTS AND DISCUSSION

Data in this report were derived from 632 ground samples from three areas in northern Missouri and three areas in southern Missouri and are presented in Tables 1–3, inclusive. Data for northern and southern Missouri were examined separately to permit direct comparisons between regional seed production on the more fertile and less fertile soils of the State. County and local differences were minimized by combining data on a regional basis to obtain general averages. Seed production should be considered below normal because of drought conditions in Missouri from 1953 until 1956.

Seeds were considered to be in two classes: *select* and *nonselect*. Select foods were those that appeared in important amounts in the diet of upland game birds in Missouri (Korschgen, 1948, 1952, 1958, 1959), while the nonselect category included all kinds taken in small amounts or not at all.

Combined data for 1954 and 1955 (Table 1) show that in northern Missouri an average of 741 sound, mature seeds were recovered per square foot of ground and topsoil sample at the end of the growing season. The average volume was 2.5 cc. per square foot in 303 samples. Select foods averaged 102 lb. per acre during the 2-year period. Nonselect foods amounted to 37 lb., for a total of 139 lb. per acre.

Comparable data from 329 southern Missouri samples (Table 1) showed an average of 513 seeds, or 2.6 cc. per square foot. Select foods amounted to 55 lb. per acre—a little more than one-half the quantity found on the more fertile northern soils. Nonselect foods averaged 52 lb. per acre (nearly equal to the amount of select foods), with a total of 107 lb. per acre.

It appears that the major quantitative difference between the two regions lies in the production of select foods. While the total weight of seed in the more fertile northern Missouri samples was 30 percent greater than in the southern samples, the amount of usable or select foods was 85 percent greater.

No attempt was made to measure the relative amounts of new and residue seed recovered from topsoil samples because no accurate measure of age determination of the seeds was known. Only sound, potentially viable seeds were counted because analyses of thousands of food-habits sam-

ples in Missouri have shown that game birds rarely eat others.

Pounds of select seeds by species and field types are presented as combined data, by region (Tables 2 and 3). In northern Missouri, cornfields, pastures, and soybean fields were the heaviest producers of game bird foods, with 135, 135, 125 lb. per acre, respectively. In southern Missouri, pasture, fallow–waste, and small grain fields produced greatest amounts, with 102, 86, and 63 lb. per acre, respectively.

Field type, method of cultivation or lack of it, method of harvest, and weather conditions have an important influence on production of wildlife food. Corn, cane, and soybean fields normally are cultivated in summer, thus containing fewer weeds than do other fields. Waste grain from harvest, nevertheless, made these among the important producers of game bird food. Both soybeans and corn had 112 lb. of waste per acre after harvest, and cane fields 31 lb. in northern Missouri. Pastures produced principally lespedeza and ragweed seed; fallow–waste areas, mainly great ragweed and beggar-ticks; and small grain fields, mostly foxtail grasses, panic-grass, and Korean lespedeza (Table 2).

By comparison, only 18 lb. per acre of waste corn was found in southern Missouri cornfields, a fact which probably reflected three factors: lower soil fertility, greater severity of drought, and method of harvest. Cane fields averaged 47 lb. per acre of waste grain, and no soybeans were grown on the sample areas. Cane, Korean lespedeza, common ragweed, and oaks were the best producers of game bird foods in southern Missouri (Table 3).

Farming methods made great differences in amount of select foods produced, particularly in cornfields mechanically picked compared with those hand-picked. Me-

TABLE 2. POUNDS PER ACRE OF SELECT FOOD IN NORTHERN MISSOURI, BY FIELD TYPE, 1954 AND 1955

Field Type	Corn	Cane	Small Grain	Soybean	Pasture	Fallow–Waste	Woodland	Average
Number of Samples	63	27	53	31	53	36	30	
PLANT SPECIES[1]								
Zea Mays	111.8	–	–	–	–	1.0	–	23.4
Lespedeza stipulacea	0.7	0.6	21.1	0.1	102.5	6.1	–	22.6
Setaria Faberii	18.4	2.7	41.6	11.3	1.6	9.5	0.1	13.9
Glycine max	–	–	–	111.8	–	–	–	11.4
Setaria glauca	1.4	2.9	31.1	0.7	6.3	3.9	0.1	7.6
Panicum dichotomiflorum	1.4	3.5	21.9	0.1	3.0	9.5	tr.	6.1
Ambrosia trifida	0.7	–	tr.	–	–	36.6	0.2	4.5
Ambrosia artemisiifolia	0.6	0.1	0.9	tr.	17.9	2.8	–	3.8
Bidens spp.	tr.	–	–	tr.	tr.	29.2	tr.	3.5
Sorgum vulgare	–	31.4	–	–	–	–	–	2.8
Quercus spp.	–	–	–	0.5	–	–	14.9	1.5
Croton capitatus	–	–	0.1	–	3.5	–	–	0.6
Vitis spp.	–	–	–	–	–	1.1	–	0.1
Rhus glabra	–	–	–	–	0.1	0.8	0.1	0.1
Triticum aestivum	–	–	0.7	–	–	–	–	0.1
Euphorbia maculata	tr.	tr.	0.3	tr.	tr.	tr.	–	0.1
Helianthus spp.	–	–	–	–	tr.	0.4	tr.	0.1
Euphorbia supina	tr.	–	tr.	–	tr.	0.1	–	tr.
Desmodium spp.	–	–	–	–	tr.	–	0.1	tr.
Croton monanthogynus	–	–	–	–	tr.	–	–	tr.
Ambrosia bidentata	tr.	–	–	–	–	–	–	tr.
Euphorbia heterophylla	–	–	tr.	–	tr.	–	–	tr.
Phleum pratense	tr.	–	tr.	–	tr.	–	–	tr.
Geranium carolinianum	–	–	–	tr.	–	–	tr.	tr.
Total	135.0	41.2	117.7	124.5	134.9	101.0	15.5	102.2

[1]Plant classification generally follows that of Fernald (1950).

TABLE 3.—POUNDS PER ACRE OF SELECT FOOD IN SOUTHERN MISSOURI, BY FIELD TYPE, 1954 AND 1955

Field Types	Corn	Cane	Small Grain	Pasture	Fallow–Waste	Woodland	Sassafras	Average
Number of Samples	50	34	62	52	33	53	45	
PLANT SPECIES								
Lespedeza stipulacea	4.7	1.0	14.3	46.0	42.9	tr.	1.2	15.2
Ambrosia artemisiifolia	1.5	1.8	32.5	26.8	25.1	0.1	0.4	13.4
Quercus spp.	–	–	–	–	–	29.6	2.2	5.1
Sorgum vulgare	–	47.2	–	–	–	–	–	4.9
Panicum dichotomiflorum	11.0	2.6	2.9	2.8	1.8	tr.	tr.	3.1
Croton capitatus	–	0.5	4.7	12.3	0.3	–	0.1	2.9
Zea Mays	18.5	–	–	–	–	–	–	2.8
Ambrosia bidentata	0.1	–	2.5	9.2	3.0	tr.	tr.	2.2
Setaria glauca	7.4	0.3	4.0	tr.	tr.	tr.	tr.	1.9
Crotonopsis elliptica	0.1	tr.	0.5	0.8	7.7	tr.	tr.	1.0
Sassafras albidum	–	–	–	–	–	–	5.9	0.8
Lespedeza striata	tr.	tr.	–	2.8	2.6	tr.	–	0.7
Strophostyles leiosperma	0.3	0.2	0.8	0.6	1.8	–	0.2	0.5
Vitis spp.	tr.	0.1	–	–	–	0.5	1.1	0.3
Croton monanthogynus	–	1.1	0.2	tr.	tr.	–	0.1	0.2
Croton glandulosus	0.1	–	0.1	0.2	0.3	–	0.1	0.1
Rhus copallina	tr.	–	tr.	–	–	0.2	0.2	0.1
Triticum aestivum	–	–	0.3	–	–	–	–	0.1
Geranium carolinianum	–	–	tr.	0.1	0.2	–	0.1	0.1
Bidens spp.	–	–	0.1	–	0.2	tr.	–	tr.
Strophostyles helvola	–	–	–	tr.	0.2	–	0.1	tr.
Setaria Faberii	0.1	–	tr.	–	–	–	tr.	tr.
Desmodium spp.	–	–	tr.	–	–	tr.	tr.	tr.
Rhus glabra	–	–	–	–	–	tr.	tr.	tr.
Helianthus spp.	–	–	–	–	–	tr.	–	tr.
Euphorbia supina	–	–	–	tr.	tr.	–	tr.	tr.
Euphorbia heterophylla	–	–	–	–	–	–	tr.	tr.
Phleum pratense	–	–	tr.	–	tr.	–	–	tr.
Total	43.7	54.8	62.9	101.6	86.1	30.4	11.7	55.4

chanically picked fields in northern Missouri, where machine harvest is the rule, yielded 201 lb. of select foods per acre, while hand-picked fields yielded only 27 lb. per acre (Table 1). Machine-harvested fields in southern Missouri yielded 159 lb. and hand-picked fields only 31 lb. per acre (Table 1). These differences result from more than just the methods of harvest: Farming with power machines is more extensive and less meticulous, and less clean than is the case when horse-drawn implements and hand tools are used in intensive cultivation of small fields. Post-cultivation spraying for weed control may curtail weed seed production to an increasing extent in cornfields of the future.

No attempt was made in this study to establish whether select foods were taken because of preference, availability, or other reasons. Availability undoubtedly plays a large part in food selection, as pointed out by Wright (1941) for upland game birds. However, Bookhout (1958) found little correlation between available plant seeds and their use by bobwhite quail in southern Illinois.

Production of select foods generally exceeded that of nonselect foods. In group collections made in 78 different type locations during the 2 years, select foods equalled or exceeded the amount of nonselect foods in 54 cases. This, in part, indicates that foods are "select" because of greater availability. Nevertheless, the very high (up to 144 lb. per acre) production of some nonselect foods indicates that other factors are involved.

Nice (1910) found that adult quail ate an average of 15 gm. of weed seed each

day (12.07 lb. of seed per bird per year). Rodents, other birds, insects, and weathering take a heavy toll of seeds, but the relative proportions taken by each are unknown. Allen (1938) commented on use of weed seeds by songbirds and mice. Michael and Beckwith (1955) found that harvester ants were important competitors for bobwhite foods in Florida. They found that a colony of ants consumed 80 to 125 gm. of food in a day's time, an amount sufficient to feed a covey of 8 to 10 quail for the same period. They also found by controlled feeding tests that the choice cotton rat foods differed sharply from those of quail, but that the next preferred rodent foods were important quail foods.

My findings show that Greene County land in fall, 1954, had insufficient select food to support one quail per acre through the year (11 lb. per acre), even if the bird ate every *select* seed available. Andrew County, with 144 lb. of select food per acre, could support about 12 birds per acre on the same basis. Yields in other counties ranged between these extremes. Select seeds identified in the samples totalled 31 different kinds; nonselect, 207.

Data presented in Missouri's Soil Sample Survey (1943) showed a statewide average of one quail per 7.9 acres. If one uses this population figure as average, sufficient food was available on a regional basis for increased fall quail populations even during the drought year of 1954, except in localized areas such as Greene County.

SUMMARY

The 632 topsoil ground samples collected from 6 areas of Missouri during 1954 and 1955 were analyzed to learn the amount of food available to upland game birds in autumn. Eight field types were sampled. Seeds were classified as select and nonselect on the basis of use by game birds. Select foods averaged 102 lb. and nonselect foods 37 lb. per acre in northern Missouri; 55 lb. select and 52 lb. nonselect seeds per acre were found in southern Missouri. Moderate to severe drought seriously affected the amount of seed produced. Cornfields, pastures, and soybean fields were the heaviest producers of game bird foods in northern Missouri, while pastures, fallow–waste areas, and small grain fields produced greatest amounts in southern Missouri. Production of select foods generally exceeded that of nonselect foods, indicating that certain items are select because of availability, although availability alone does not explain food habits of game species.

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DEER FORAGE INCREASED BY THINNINGS IN A LOUISIANA LOBLOLLY PINE PLANTATION

Robert M. Blair

Southern Forest Experiment Station, Forest Service, U. S. Department of Agriculture, New Orleans, Louisiana

This paper relates how understory vegetation, especially browse important to deer, was increased by different intensities of thinning in a loblolly pine (*Pinus taeda*) plantation in central Louisiana. Similar plantations exist or are being established on millions of acres in the South and will comprise a large portion of the region's future deer range. The findings reported here may also apply to a substantial additional acreage being direct-seeded to pine.

CHARACTERISTICS OF THE STUDY PLANTATION

Loblolly seedlings had been planted in 1928 at an 8- by 8-foot spacing. The area is relatively flat, but surface water usually drains promptly. Soils are fine sandy loams with moderately good internal drainage. The site index for loblolly pine ranges from 85 to 95 feet, which is above average for the uplands of central Louisiana. Fire has been excluded and grazing by cattle and deer has been very light.

In 1948, and again in 1953, randomized plots within the plantation were thinned to three intensities—to residual basal areas of approximately 100, 85, and 70 square feet of pine per acre. On an additional set of plots, initial thinning to 85 square feet was deferred until 1953, when the trees were 25 years old. Each thinning treatment was replicated four times on 0.4-acre plots; only pines were removed. By 1957, pines formed the dominant and more continuous canopy, hardwoods and tall shrubs the lower and less distinct canopy.

Hardwood stocking was inversely related to pine density (Table 1). The interspersion of hardwoods over 1.5 inches d.b.h. decreased the variation in the total basal area between pine-thinning treatments and hampered the establishment and growth of understory vegetation.

Sweetgum (*Liquidambar styraciflua*) was the predominant hardwood tree species, comprising 71 percent of the total stems. Blackgum (*Nyssa sylvatica*) was next in importance, averaging 12 percent of the stems. Less prevalent trees and large shrubs included southern red oak (*Quercus falcata*), water oak (*Quercus nigra*), red maple (*Acer rubrum*), flowering dogwood (*Cornus florida*), tree huckleberry (*Vaccinium arboreum*), and haws (*Crataegus* spp.).

Litter was composed mainly of pine straw. Its depth varied inversely with thinning intensity, from 1.1 inches under heavy thinning to 1.6 under light thinning.

Rainfall in 1957 totaled 77 inches, about

TABLE 1.—TIMBER STAND CONDITIONS IN THE FALL OF 1957 (trees larger than 1.5 inches d.b.h.)

Stand and Stock Data for Pine and Hardwoods	PINE-THINNING TREATMENTS		
	Light	Medium	Heavy
Trees per acre (number)			
Pine	238	225	172
Hardwood	175	195	272
Total	413	420	444
Basal area (sq. ft. per acre)			
Pine	118	107	92
Hardwood	6	10	14
Total	124	117	106
Average d.b.h. (inches)			
Pine	10	9	10
Hardwood	2	3	3
Average height to base of live crown on selected pine-crop trees (feet)	37	36	36

19 inches above average. Fifty-one percent of this occurred during the growing season, March to September.

METHODS

Yields were measured in October 1957, just prior to the third scheduled pine thinning. The current season's growth of leaves and stems of herbaceous and woody forage was clipped to a height of 5 feet on 9 milacre quadrats in the central 0.1 acre of each 0.4-acre plot. Grasses and grasslike plants (Cyperaceae) were sampled separately. Forbs were divided into three categories—composites, legumes, and miscellaneous species. Browse (twigs and leaves of shrubs, hardwood trees, and woody vines) was sampled by species or species groups. Clipped forage was air-dried for a minimum of 1 month and then placed in a forced-draft oven for 72 hours at 65°C. All forage yields herein reported are in terms of the oven-dry material.

The dried twigs of deciduous and semi-evergreen browse species were stripped of leaves and redried for 24 hours. The twig weights were then combined with the weights of leaves and twigs of evergreen species for calculation of the total availability of browse during the fall and winter.

TABLE 2.—FORAGE PRODUCED IN OCTOBER 1957 UNDER PINE STANDS THINNED AT DIFFERENT INTENSITIES (all values in pounds per acre)

Class of Vegetation	PINE-THINNING TREATMENTS		
	Light	Medium	Heavy
Browse	154	179	199
Grasses	38	70	70
Grasslike plants	3	7	5
Forbs	20	20	25
Composites	7	10	10
Legumes	2	2	3
Misc.	11	8	12
Total forage	215	276	299

Palatability groupings were based on local observations and on studies by Goodrum and Reid (1959) and Lay (1957).

RESULTS

Production of understory vegetation was directly related to pine-thinning intensity (Table 2). Total forage yields were 215 pounds per acre under light thinning, 276 pounds under medium thinning, and 299 pounds where thinning was heaviest. The relatively small difference in total forage yields between the medium and heavy thinnings was probably attributable to the greater number of hardwoods in the overstory of heavily thinned stands.

More than two-thirds of the total forage was browse. The proportion of browse considered palatable to deer varied from 64 percent in October to 76 percent during the late fall and winter (Table 3). The production of palatable browse, which was in direct relation to thinning intensity, was 52 percent greater under heavily thinned

TABLE 3.—BROWSE AVAILABLE PER ACRE IN OCTOBER 1957 AND DURING THE FOLLOWING LATE FALL AND WINTER (all values in pounds per acre)

Class of Browse and Season	PINE THINNING		
	Light	Medium	Heavy
Palatable			
October	90	112	137
Late fall and winter	57	72	85
Nonpalatable			
October	64	67	62
Late fall and winter	19	33	16

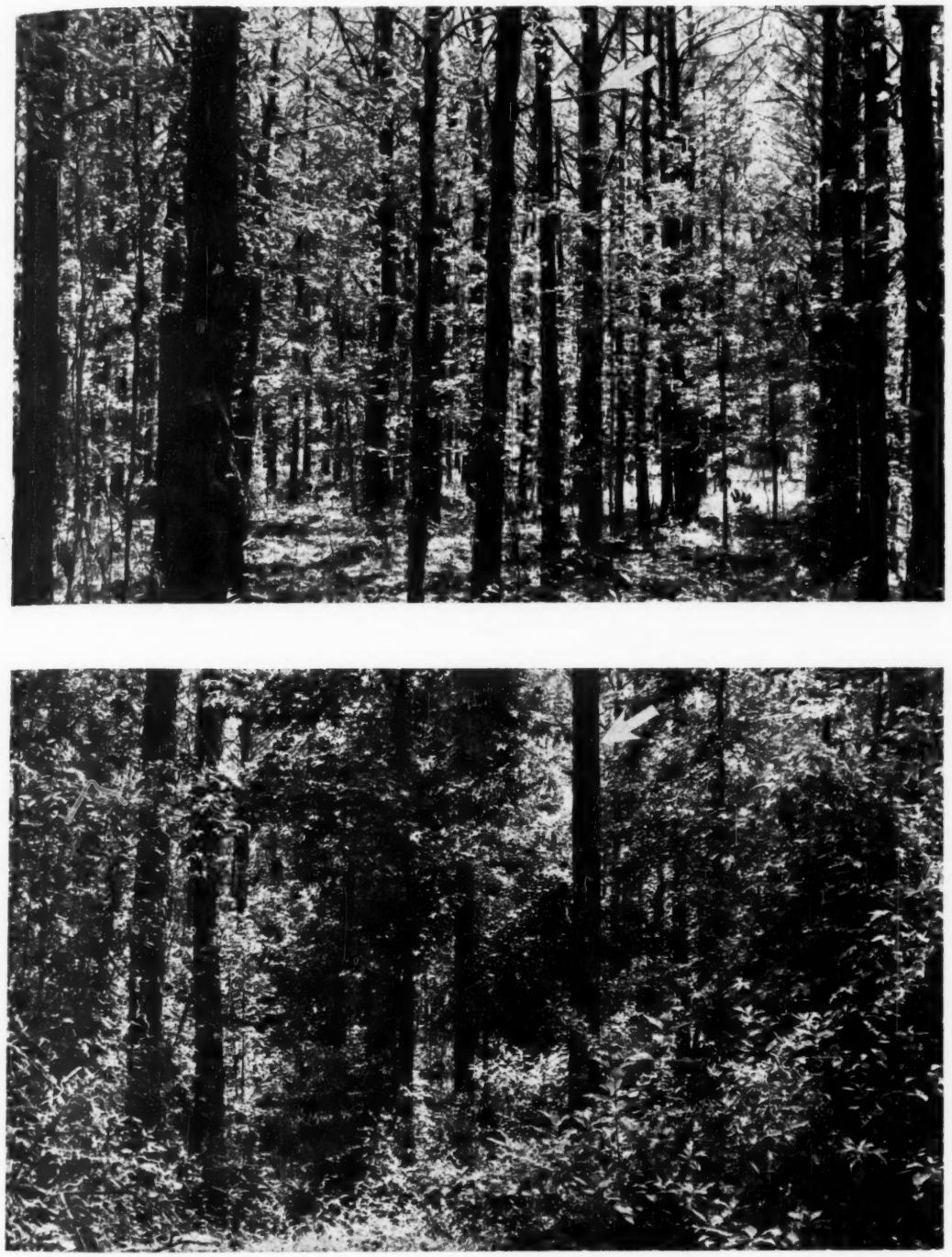

FIG. 1. *Above.* — The study plantation at age 20. Browse plants were scarce in the understory. *Below.* — The same camera point 10 years later. After two heavy thinnings for pulpwood, the plantation was producing 137 pounds of palatable browse per acre.

TABLE 4.—PRODUCTION (in pounds per acre) OF PALATABLE DEER BROWSE IN SUMMER AND WINTER UNDER DIFFERENT PINE-THINNING INTENSITIES

Class and Species	LIGHT THINNING		MEDIUM THINNING		HEAVY THINNING	
	Summer	Winter	Summer	Winter	Summer	Winter
VINES						
Rattan (*Berchemia scandens*)	16.8	11.8	16.5	11.6	26.8	18.8
Crossvine (*Bignonia capreolata*)	.0	.0	.5	.5	1.7	1.7
Trumpetcreeper (*Campsis radicans*)	.0	.0	2.0	.8	.9	.3
Yellow jessamine (*Gelsemium sempervirens*)	28.8	28.8	40.5	40.5	43.8	43.8
Virginia creeper (*Parthenocissus quinquefolia*)	.8	.5	.6	.3	.5	.3
Greenbriers (*Smilax bona-nox, S. glauca, S. lanceolata, S. rotundifolia*)	3.4	3.1	8.7	7.6	6.4	5.5
Muscadine grape (*Vitis rotundifolia*)	2.2	.9	1.9	.8	4.7	2.0
SHRUBS AND HARDWOOD TREES						
St. Andrewscross (*Ascyrum hypericoides*)	1.2	.4	.2	.1	.3	.1
St. Peterswort (*Ascyrum stans*)	.4	.1	.3	.1	1.6	.5
French mulberry (*Callicarpa americana*)	8.9	2.3	11.5	2.9	30.7	7.7
Flowering dogwood (*Cornus florida*)	.1	T[1]	.1	T	2.4	.6
Haws (*Crataegus* spp.)	T	T	.5	.1	.3	T
White ash (*Fraxinus americana*)	.0	.0	.7	.1	.0	.0
Deciduous holly (*Ilex decidua*)	1.7	.2	8.6	.8	1.1	.1
Yaupon (*Ilex vomitoria*)	.0	.0	.0	.0	1.1	1.1
Sweetbay (*Magnolia virginiana*)	T	T	.0	.0	.0	.0
Blackgum (*Nyssa sylvatica*)	6.2	.8	5.3	.6	8.5	1.0
Water oak (*Quercus nigra*)	2.6	.5	.7	.1	1.8	.3
Willow oak (*Quercus phellos*)	.2	T	.0	.0	T	T
Poison oak (*Toxicodendron quercifolium*)	1.2	.2	.4	.1	.2	.1
Blackberries and dewberries (*Rubus* spp.)	3.6	1.3	11.3	4.2	2.3	.9
Sassafras (*Sassafras albidum*)	T	T	.3	.1	.9	.2
Bigleaf snowbell (*Styrax grandifolia*)	.0	.0	.0	.0	.4	.1
Elliott blueberry (*Vaccinium elliotti*)	12.1	6.0	1.3	.6	.1	.1
Total palatable browse	90.2	56.9	111.9	71.9	136.5	85.2

[1] Less than .05 pound per acre.

stands than under those lightly thinned (Fig. 1).

Production of palatable browse during the summer averaged 113 pounds per acre as contrasted to 71 pounds per acre in late fall and winter—a drop of 37 percent. This sharp decline following leaf-fall illustrates the necessity of basing the carrying capacity of year-round deer ranges on winter forage.

Vines were the major source of palatable browse under all intensities of thinning (Table 4). They were especially important during the late fall and winter. For example, 10 of the 11 species on the study plantation made up 61 percent of the summer's yield of palatable browse and 84 percent of that available in the winter. Yellow jessamine (*Gelsemium sempervirens*), rattan (*Berchemia scandens*), and greenbriers (*Smilax* spp.) were the predominant species.

French mulberry (*Callicarpa americana*), blackgum, Elliott blueberry (*Vaccinium elliotti*), and dewberries (*Rubus* spp.) and blackberries were the most common shrubs and trees contributing to yields of desirable forage. These species produced 30 percent of the palatable browse in summer but only 13 percent in winter.

Yields of nonpalatable browse, as distinguished from those of palatable browse, were practically the same for all thinning treatments. Red maple, sweetgum, waxmyrtle (*Myrica cerifera*), southern red oak, blackjack oak (*Quercus marilandica*), and low-growing blueberries (*Vaccinium* spp.)

were the most abundant species of undesirable browse.

Plots in which the first thinning was deferred until age 25 had the same amount of total browse in 1957 as did those thinned moderately at age 20. The proportion of palatable browse to total browse, however, was less under the deferred thinning—54 percent as compared to 63; the palatable species did not gain dominance in the woody understory until about 5 years after initial thinning.

Herbaceous plants yielded less forage than woody species (Table 2). Yields of grass and grasslike plants were 41 pounds per acre on lightly thinned plots and approximately 75 pounds under both medium and heavy thinning. The greater density of shrubs and hardwoods on heavily thinned plots prevented the grass yields from increasing appreciably beyond those under the medium thinning.

Carpet grass (*Axonopus affinis*), arrowfeather threeawn (*Aristida purpurascens*), and several species of uniolas (*Uniola* spp.), bluestems (*Andropogon* spp.), panicums (*Panicum* spp.), and paspalums (*Paspalum* spp.), were the most numerous grasses. Beakrushes (*Rhynchospora* spp.) and sedges (*Carex* spp.) were the principal grasslike plants.

Forb production was low on all plots. Principal species were grassleaf goldaster (*Chrysopsis graminifolia*), sunflowers (*Helianthus angustifolius* and *H. hirsutus*), bonesets (*Eupatorium* spp.), ironweed (*Vernonia texana*), milk pea (*Galactia regularis*), trailing lespedeza (*Lespedeza procumbens*), and skullcap (*Scutellaria* spp.).

PINE THINNING AND CARRYING CAPACITY

Differences in the amount of desirable browse were quite important when related to deer carrying capacity. For example, lightly thinned plots had an average of 57 pounds of desirable browse during the critical winter season. Under an assumed proper-use factor of 40 percent utilization of winter browse, 4.7 pounds of dry matter intake per day (French, *et al.*, 1956), and a diet composed entirely of palatable browse, approximately 75 acres would be necessary to support a 150-pound deer for a year. The heavily thinned plots had 85 pounds of palatable forage per acre in winter; here a minimum of 50 acres would be needed to furnish yearlong range for a 150-pound deer.

An important influence on the deer carrying capacity of pine plantations is the development of hardwoods beneath the pine overstory. When the hardwoods grow beyond the reach of deer, as they will do sooner with heavy pine thinning than with light, forage can be increased by deadening those hardwoods that are of no importance in mast or timber production.

SUMMARY

A loblolly pine plantation in central Louisiana was thinned at age 20 and again at age 25 to residual basal areas of approximately 100, 85, and 70 square feet of pine per acre.

By age 29, stands were generally two-storied, with hardwoods beneath the dominant pines. Stocking of hardwoods was in direct relation to thinning intensity and correspondingly limited the growth of understory vegetation suitable for deer forage. The combined yields of browse, grasses, grasslike plants, and forbs varied from 215 pounds per acre under light thinning to 299 pounds under heavy thinning. Browse palatable to deer ranged from 90 pounds per acre under light thinning to 137 pounds under heavy thinning. Yields of nonpalatable browse were similar under all intensities of thinning. Palatable browse available during the winter averaged 63 percent of the summer's production.

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EVALUATION OF A FOX POPULATION INDEX

Charles W. Lemke and Donald R. Thompson

Wisconsin Conservation Department, Madison, Wisconsin

A questionnaire regarding foxes was originated in 1949 by D. R. Thompson and S. H. Richards with the aid of Wisconsin Federal-State Crop Reporting Service statisticians. It was intended to provide an annual index to fox population levels. Our purpose is to analyze the results and to point out the applicability of this general technique as an inexpensive wildlife population index.

The Wisconsin Crop Reporting Service cooperates with the Conservation Department on several mailed questionnaire surveys concerning wildlife populations. Crop Reporting Service statisticians feel that an occasional wildlife questionnaire is of interest to their cooperators. We are deeply indebted to the Service for assisting in preparation and distribution of the questionnaires. We edit replies and sometimes help in summarizing the data. We wish especially to acknowledge the cooperation of C. D. Caparoon and O. E. Krause of the Wisconsin Crop Reporting Service, and of J. H. Torrie of the University of Wisconsin for statistical advice.

The Questionnaire

The questionnaire is sent out in late August and is made up of the following questions:

1. Have you seen any fox on your farm since May 1?
   Yes ..... No .....
2. Do you know of any fox litters raised on your farm this year?
   Yes ....., No .....
3. Have you lost any poultry this year which you are certain was due to fox?
   Yes ..... No ..... Number .....

The percentage of "yes" replies to each question furnishes a fox population index. To preserve simplicity and to avoid possible confusion of species, reporters are not asked to distinguish between the gray fox (*Urocyon cinereoargenteus*) and the red fox (*Vulpes fulva*). In the years covered by this study the gray fox made up only about 15 percent of the foxes bountied in Wisconsin.

No changes have been made in the wording of these questions since their design in 1949. Through 1951, the fox questionnaire was sent to approximately 2,000 farmers throughout the State. In 1952, it was combined with a pheasant questionnaire. This latter form was distributed to approximately 4,000 farmers each year. Questions on ruffed grouse (*Bonasa umbellus*), prairie grouse (*Tympanuchus cupido* and *Pedioecetes phasianellus*) were added in 1957.

Response Rate

The response rate on this wildlife questionnaire (Table 1) compares favorably with the usual 50 percent response rate on regular agricultural questionnaires sent to the same farmers. A slight downward trend is apparent in the number of replies to each of the questions from the first to last. This is expected in mailed questionnaires (Parten, 1950:216). Difficulty of the question may also affect response. The greatly reduced response to the second part of the third question (Table 2) may result from a considerable increase in the difficulty of this question in addition to the position effect.

This question asks for the number of poultry lost to foxes. Thus only farmers that have suffered losses to foxes are eligible to answer. Only about two-thirds of those that have suffered losses will estimate the number lost, a fact which suggests that the estimate may be difficult to make. The farmer is undoubtedly aware of the occurrence of losses to foxes and other causes, but the difficulty arises when he attempts to assign exact numbers to each known cause of loss. Few farmers have precise figures on the number of birds in their flocks, especially day by day, as would have to be the case if

TABLE 1.—RESPONSE TO NUMBERED QUESTIONS

Year	Number Sent	Response Rate to Question		
		No. 1	No. 2	No. 3
1949	1,863	49.4	48.8	48.5
1950	1,729	58.1	57.4	57.0
1951	1,776	54.6	53.3	52.2
1952	3,810	53.4	51.7	51.7
1953	3,721	50.8	49.9	49.2
1954	3,735	61.1	60.0	58.9
1955	3,929	49.0	48.1	47.4
1956	4,253	45.4	44.5	43.6
1957	4,258	46.5	45.8	44.9
1958	4,487	45.5	44.2	43.5
1959	4,175	45.1	43.9	41.7
Average		50.8	49.8	48.9

they were to give an exact answer to this question. Failure to answer this question may be a reflection of the honesty of the farmers. Those that answer are estimating losses as closely as possible.

Non-response Bias

Non-response bias may be present in any survey which depends on voluntary replies. If the percentage returned can be held constant, this bias may be relatively unimportant in an index. Examination of Table 1 shows that there is some variation in the percentage of replies to each question from year to year. This leads to speculation that a relationship may exist between the response rate and the fox population level. For instance, there may be a tendency for a person to answer the questions or return the report only if he can answer in the affirmative. This possibility was examined by calculating correlation coefficients (r) between the percentage of replies to each of the four fox questions and the annual bounty records. Because of temporary interruptions in State bounty payment in 1953 and 1957, only the records of 7 years are available for this correlation. No significant relationships were found so that we are unable to say that response varied with population level. Correlation coefficients varied from –0.378 to 0.476, and the value required for significance at the 0.05 level is 0.754 for 5 d.f. (Snedecor, 1946:149).

The slight tendency for the return to decline is probably more logically explained by reviewing the history of the fox questionnaire. During its transition to a special wildlife questionnaire, the subjects included have increased from one species to four, and the number of questions has grown from 4 to 13. A lengthy and cumbersome questionnaire is known to discourage response (Parten, 1950:157, 217, and 383). Thus we might expect a decline in the response rate simply from the changes mentioned, all of which necessarily increase the length of the questionnaire.

TABLE 2.—RESPONSE TO QUESTION ON NUMBER OF POULTRY LOST

Year	Number of Reporters		Percent Losing Poultry That Estimate Number Lost
	Losing Poultry	Estimating Poultry Lost	
1949	65	47	72
1950	57	39	68
1951	69	52	75
1952	194	119	61
1953	193	113	58
1954	228	156	68
1955	155	95	61
1956	169	100	59
1957	178	102	57
1958	235	136	58
1959	294	153	52

BOUNTY RECORDS AS A POPULATION-TREND INDEX

Further analysis of the questionnaire depends on the validity of using bounty records as a trend index. Fox-bounty records have been criticized as a population index by Seagears (1944). He reported a direct relation between numbers of bounty claims and pelt prices, and many authors present solid evidence of false claims, thereby raising the question of the validity of bounty records as a population index.

Under the Wisconsin bounty system the State pays $2.50 for each adult and $1.00 for each kit. Counties are allowed to pay an additional bounty if they wish. Thus a fox hunter may collect both a State and a county bounty. Only State bounty records are considered here. Bounty rewards and pelt

prices have remained quite stable during the period of this analysis. Pelt prices ranged from \$0.36 to \$0.98, averaging \$0.57. The State bounty has been constant at \$2.50 for adult and \$1.00 for kits. Surveys of county clerks in 1952 and 1957 showed no important changes in county bounties. In 59 counties, rewards varied from \$1.50 to \$2.50 for adult foxes and \$1.00 to \$2.50 for kits. Eleven counties paid no bounty and only one paid a higher bounty reward than did the State. If the inflationary trend of our economy is considered, it appears that the monetary incentive for taking foxes has declined, while the harvest has increased. If harvest depends only on monetary incentive it should have declined. The fact that it increased means other factors are operating. The most obvious possibility is an increase in the fox population level.

Richards and Hine (1953) concluded that bounty payments have had little effect on the fox population itself in Wisconsin and are not believed to have influenced the take of foxes out of proportion to the actual population. They compared den counts made on a 36-square-mile study area in Grant County to the bounty records for that county over an 8-year period. These data yield a correlation coefficient of 0.733 (0.707 required for 0.05 level, 6 d.f.). Further verification of fox bounties as an index was obtained from a comparison of fox population estimates on a 4,500-acre study area in Columbia County with the Columbia County bounty records. The study area population was estimated by direct observations and shows a trend parallel to the bounty records. The correlation coefficient calculated from these data is 0.895 (0.641 required for 0.01 level, 13 d.f.). Thus we accept the State bounty records as a reliable index to the State fox population.

Bounty Records during Period of Analysis

Although the Crop Reporting Service fox questionnaire has been sent out each year since 1949, only 7 years of bounty records are available for comparison. Interruptions in State bounty payments occurred in the following periods: July 1–November 7, 1953; July 1–August 11, 1955; and from July 1, 1957, to December 25, 1959.

The interruption in 1953, July 1 to November 7, covers the most important period of the year. Upwards of 50 percent of the annual claims are normally submitted during this period. Since this interruption is too great to warrant using the data without a correction, 1953 has been omitted from the comparisons. The brief interruption in 1955 had only a minor effect on the total fox harvest for fiscal 1955–56. Normally only about 6 percent of the annual claims are submitted from July 1 to August 31. The fact that the bounty system was reinstated on August 11, 1955, means that total claims for the year were probably only about 4 percent low. The actual error might be less than 4 percent. Most of the animals not taken during this short period would have been available for harvest when bounty payments were resumed in August. Some carcasses taken during the period of interruption could have been held over in anticipation of the reinstatement of bounties.

QUESTIONNAIRE VS. BOUNTY RECORDS

It is of first importance to establish that the questionnaire index follows the statewide population trend. Figs. 1 through 4 depict the relationship between the statewide indices calculated from each question and the statewide bounty records. The correlation coefficients are highly significant for Figs. 1, 2, and 3, since a value of 0.874 is required at the 0.01 level, 5 d.f.

Thus the rates of affirmative answers to each of the first three questions all give close agreement with the trend shown by the bounty records. Agreement in the second and third questions could be caused in part by an "internal" relation with the first question. The answer to one may suggest the answer to the next. The relationship to bounty records of the average number of head of poultry lost because of foxes (Fig. 4) is considerably below that required for significance at the 0.05 level (0.754, 5 d.f.). Possible reasons for this are difficulty of the question, already discussed, and the fact that fox predation on poultry is related

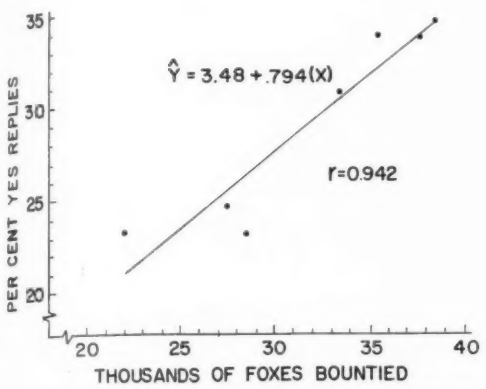

FIG. 1. Percentage of "yes" replies to question no. 1—"Have you seen any fox on your farm since May 1?" vs. foxes bountied in Wisconsin 1949–50 through 1956–57.

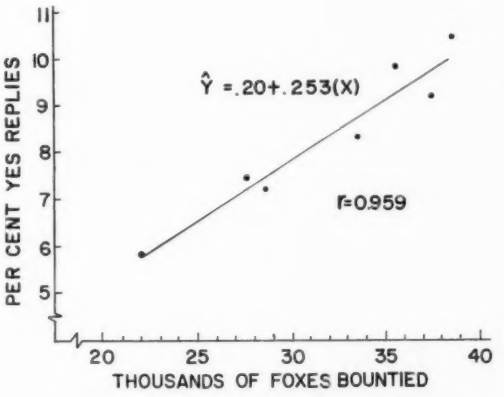

FIG. 3. Percentage of "yes" replies to question no. 3—"Have you lost any poultry this year which you are certain was due to fox?" vs. foxes bountied in Wisconsin, 1949–50 through 1956–57.

partly to abundance of natural prey, and to prevailing poultry husbandry practices.

Subdivision of Sample

This sample can provide more information for both research and management if it can be regionally subdivided. Furthermore, if enough information is at hand to assure that stratification can be carried out properly, the knowledge should result in an improvement in precision of the index (Cochran, 1953). The purpose of stratification is to select strata in which the population is more homogeneous than the population at large. We do not have sufficient population data to stratify objectively, but the bounty records and the questionnaire data at hand are of help in making subjective divisions. These data are shown in map form in Figs. 5 and 6. The apparent disagreement between these two maps does not mean that one source is more nearly correct than the other. One represents animals bountied and the other, foxes seen on farms.

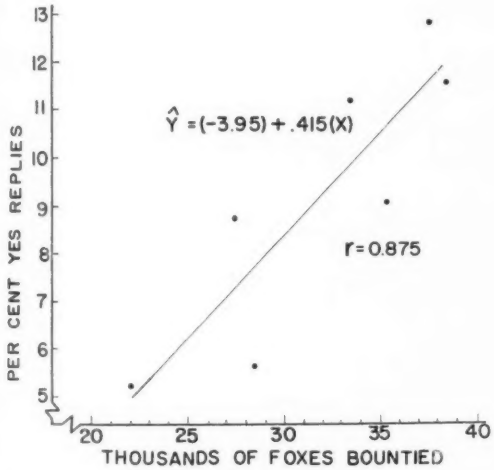

FIG. 2. Percentage of "yes" replies to question no. 2—"Do you know of any fox litters raised on your farm this year?" vs. foxes bountied in Wisconsin 1949–50 through 1956–57.

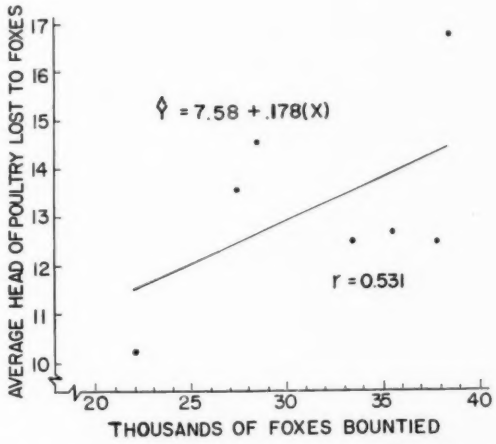

FIG. 4. Annual averages of head of poultry lost to fox, second part of question no. 3 vs. foxes bountied in Wisconsin, 1949–50 through 1956–57.

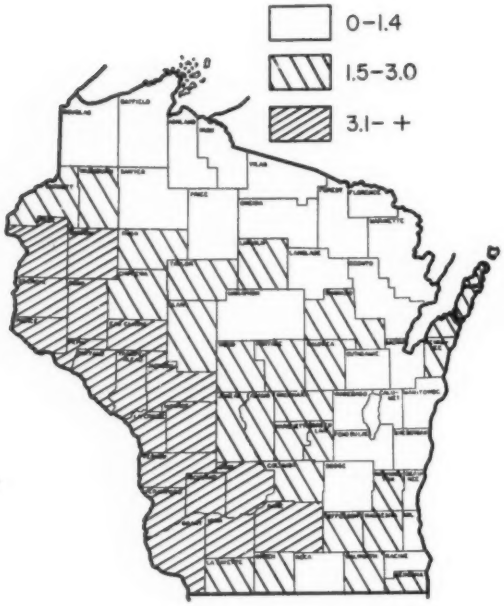

FIG. 5. Foxes bountied per square mile. Wisconsin 1953–54 through 1956–57.

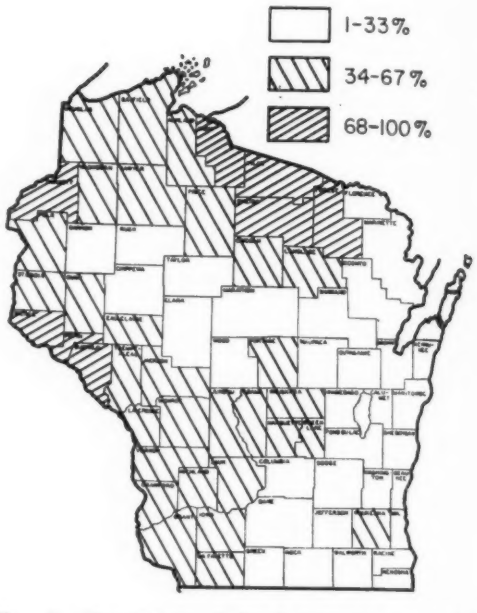

FIG. 6. Percentage of "yes" answers to question no. 1. Wisconsin 1953 through 1956.

The low density of county claims in the north may be in part due to lower human populations and a far more attractive quarry for trappers in the coyote, on which the State pays a $20.00 bounty and counties pay none. In areas where coyotes are more numerous, trappers may consider the fox a nuisance (Switzenberg, 1951). The high-density area of the north shown by the questionnaire data undoubtedly reflects the attraction that openings and farmland hold for the red fox in our forest counties. Northern counties showing the highest occurrence of foxes seen on farms average only 22 percent of total land area in farms. The southern part of the State is about 85 percent farmland (Wisconsin Crop and Livestock Reporting Service, 1954).

Since each map may show densities peculiar to the source of its data, consideration of these data along with major geographical features lead to a division of the State into three areas. They are arbitrarily named for the most prevalent features: (1) northern forest; (2) agricultural driftless; and (3) agricultural glaciated (Fig. 7).

Correlation coefficients calculated for the results of the first three questions and the bounty records from the corresponding stratum (Table 3) show significant relationships to exist in all cases.

FIG. 7. Subdivision of Wisconsin fox range.

TABLE 3.—CORRELATION COEFFICIENTS* BETWEEN QUESTIONNAIRE INDEX AND BOUNTY CLAIMS, WITHIN STRATA

Question	Forest Area	AGRICULTURAL AREA	
		Driftless	Glaciated
No. 1	0.931	0.908	0.794
No. 2	0.777	0.783	0.954
No. 3	0.757	0.784	0.822

* 0.754 required for 0.05 level and 0.874 required for 0.01 level, 5 degrees of freedom.

A test of homogeneity (Snedecor, 1946) among these values of r yields a chi-square value of 5.62, which is not significant (19.675 required for significance at the 0.05 level with 11 d.f.). Thus these correlation coefficients cannot be said to differ from statewide values. At the same time, significance is shown to be retained on the subdivided basis despite the smaller sample sizes in each area. Thus it appears that this method can provide information on population trends in areas within the State as well as on a statewide basis. The correlation coefficient is an estimate of the degree to which two variables vary together. Any given value of r may arise from data of other slope and/or intercept. Although highly correlated, the bounty figures and percentage of "yes" replies from crop reporters may bear different ratios to each other among the three areas, in addition to the populations being at different levels. Further analyses are not attempted since neither of the original sets of data are true population indices.

CONCLUSIONS

This questionnaire provides a fox population index that appears to be as good as the bounty records. The sample has been subdivided without losing the relationship between indices, even though it cannot be shown at this time to have resulted in an improvement over the statewide relationship. Further improvements in stratification may be possible when accurate information on fox population density is obtained.

Mailed questionnaire surveys of game populations have a number of valuable features:

1. They are economical. Once the procedure is established it can be carried out by non-technical personnel. Several species can be included on one questionnaire.

2. They provide rapid and timely coverage of the entire state or any part desired. The bulk of the return is received within 2 weeks of the mailing date.

3. They can provide a continuous source of data, less influenced by personnel changes than other census methods or, in this case, changes in bounty payments.

4. Their application makes it practical to collect information on distribution and population trends of less immediately important game species, and on the non-game species that may be important to both game and human populations. A backlog of such information is important to future population studies. Questionnaires may be of limited value in areas of low human populations, or where human populations are unevenly distributed. Since it is desirable to keep the questionnaires as simple as possible, it may not be possible to get more than trend indices.

SUMMARY

Fox questionnaires have been mailed to 2,000 to 4,000 farmers through the Wisconsin Crop Reporting Service each summer since 1949. Response averaged 50 percent with very few unusable returns. The percentage of positive reports of foxes was evaluated as a population index by comparing it with existing fox bounty claims. Significant relationships between reports and claims were found at the statewide level and also within three subdivisions. The results suggest that questionnaires of this type may provide inexpensive population indices for other species.

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ESTABLISHMENT OF WILDLIFE FOOD PATCHES IN SOD WITHOUT TILLAGE[1]

K. P. Buchholtz and D. E. Bayer[2]

Department of Agronomy, University of Wisconsin, Madison, Wisconsin

In recent years acceptance of chemicals for use in the control of undesirable vegetation in agricultural crops has increased. This has prompted several investigations into the possible use of chemicals for the establishment of wildlife food patches. Wildlife conservation activities are usually associated with land that cannot be farmed profitably. However, small scattered areas in land unfit for farming are usually satisfactory for the location of food patches for wildlife. These areas are likely to be covered with a dense stand of perennial grasses which must be controlled in some manner if planted crops are to be established as a food patch. When the grasses are controlled, growth of annual weeds may become abundant enough to impair the growth of the planted crops.

Traditionally, soil covered with perennial grasses is prepared for cropping by plowing and other tillage operations. This is not practical in establishment of food patches because of their small size and because they are often in remote locations. Several attempts have been made to use chemicals to kill perennial grasses in sod before planting a crop. Thompson and Kabat (1956) reported on trials located in Wisconsin in which dalapon was used in an attempt to kill bluegrass (*Poa* spp.) and quackgrass (*Agropyron repens*) sods. Bluegrass was killed more completely than was quackgrass by the dalapon application. In several instances there was injury to corn (*Zea Mays*) planted on treated areas because of residues of dalapon in the soil after planting. On some treated plots annual weed growth was heavy enough to reduce the yields of corn. Zorb, *et al.* (1956) stated that in Michigan dalapon was used successfully to control quackgrass in areas later planted to corn. In certain instances injury to the corn resulted from the residue of dalapon in the soil. Bayer and Buchholtz (1958) presented data indicating that applications of simazine and combinations of dalapon and simazine were effective in controlling quackgrass and a number of annual weeds in food patches planted to corn. No injury to the corn occurred when the chemicals were applied early in the spring. The results of three trials in which food patches of corn were established on sodded areas after chemical treatment are presented.

METHODS AND MATERIALS

The first trial was established in 1957 near Madison, Wis., on an area which had not been cropped for 4 years. Small plots, 15 by 25 ft. in size, were laid out on a heavy quack-

[1] Contribution from the Department of Agronomy, Wisconsin Agricultural Experiment Station. Published with the approval of the Director of the Wisconsin Agricultural Experimental Station. Acknowledgment is made of partial support of this study by the Pittman-Robertson Projects W-9-R and W-78-R of the Wisconsin Conservation Department.

[2] Present address: Department of Botany, University of California, Davis.

grass sod. The soil, of the Miami silt loam type, was relatively low in fertility and organic matter. Considerable litter was present on the soil at time of treatment but was not disturbed. Chemical applications were made on May 6, 1957, with a small sprayer, mounted on bicycle wheels, that was adjusted to deliver water equivalent to 20 gal. per acre. Chemical treatments included the sodium salt of dalapon (2,2–dichloropropionic acid)[3] applied at 4 and 8 lb. per acre, amitrol (3–amino–1,2,4–triazole) applied at 4 lb. per acre, and simazine (2–chloro–4,6–bis(ethylamino)–s–triazine) applied at 4 and 8 lb. per acre. Combinations of dalapon and amitrol at 4 + 4 lb., amitrol and simazine at 4 + 4 lb., and dalapon, amitrol and simazine at 2 + 2 + 4 lb., on the acre basis, were also applied. Rates of application for dalapon were on the acid-equivalent basis and for other materials on the active-ingredient basis. Plots without any chemical treatment were included for comparison. Additional plots, one treated with dalapon at 4 lb. per acre and four with the combinations of chemicals, were fertilized with 500 lb. per acre of a 10–10–10 analysis fertilizer on May 7. The fertilizer was weighed for each plot and distributed by hand on the surface as uniformly as possible. Four replications of all treatments were made using a randomized complete block design.

On May 29 and 31, Wisconsin corn hybrid W 530, an early maturing hybrid, was planted on each plot with a hand planter. Four rows, spaced 40 in. apart, were established on each plot and planted at a rate estimated to give 15,800 plants per acre. No further care was given any of the plots during the growing season. On August 13, the plots were rated for quackgrass growth remaining on the plots and for the amount of annual weed growth that had developed. In each case a scale of from 0 to 10 was used. The ear corn was harvested from each plot in early October. The ears were dried to a constant weight in a forced-draft air drier, weighed and their yields calculated. The yield data were analyzed and statistically significant differences determined by use of the multiple range test described by Duncan (1955). This test identifies values in groups that do not differ significantly.

Plots receiving eight of the most promising treatments in the 1957 trial were used in a second trial in 1958. Plots in two replications were treated with dalapon and simazine at 4 + 4 lb. per acre on April 18, 1958. Comparable plots in the remaining two replications were treated with simazine alone at the rate of 4 lb. per acre on June 9, 1958. On June 3, 1958, corn hybrid W530 was planted with a hand planter in five rows, spaced 40 in. apart in each plot, to secure a stand of approximately 17,400 plants per acre. The rows in 1958 were placed between those planted in 1957. Immediately after planting the corn, ammonium nitrate was applied by hand to all plots at the rate of 150 lb. per acre. No further care was given any of the plots during the remainder of the season. The ears of corn were harvested on September 30, dried, and weighed as in the previous year.

The third trial was conducted in the Storr's Lake Public Hunting Ground in Wisconsin in 1958. Plots 15 by 30 ft. in size were established in an area heavily infested with an old stand of bluegrass (*Poa pratensis*). A heavy litter present on the soil at time of treatment was left intact. Applications used were dalapon at 8 lb. per acre, simazine at 8 lb. per acre, and a combination of dalapon and simazine at 4 + 4 lb. per acre. An untreated plot was included for comparison. Four replications were used. On May 10, 1958, a sprayer mounted on bicycle wheels was used to apply the chemical in water equivalent to 20 gal. per acre. Corn hybrid W530 was planted on June 4 in four rows spaced 3 ft. apart at a rate intended to give a stand of 21,800 plants per acre. Immediately after planting, ammonium nitrate was applied by hand to all plots at the rate of

[3] Appreciation is expressed to The Dow Chemical Co., Midland, Mich., for supplies of dalapon (Dowpon); to Amchem Products, Inc., Ambler, Pa., for supplies of amitrol (Weedazol); to Geigy Agricultural Chemicals, Yonkers, N. Y., for supplies of simazine (Simazine 50W).

TABLE 1.—WEED CONTROL AND CORN GROWTH ON FOOD PATCH PLOTS AT MADISON IN 1957

Chemical Treatment May 6, 1957	Rate (lb./A.)	10–10–10 Fertilizer Application May 7, 1957 (lb./A.)	Weed Growth Indexes[1] August 13, 1957		Corn Stand (plants/A.)	Corn Yield[2] (bu./A.)	Cost ($/bu.)
			Quackgrass	Annual Weeds			
Dalapon + amitrol + simazine	2+2+4	500	1.3	1.0	9600	45.6a	1.08
Dalapon + simazine	4+4	500	2.0	1.0	10500	43.4a	0.98
Dalapon + simazine	4+4	—	3.3	1.8	11200	32.5a	0.79
Dalapon + amitrol + simazine	2+2+4	—	3.3	2.8	9100	33.4a	0.98
Simazine	8	—	2.0	1.0	8700	32.7a	1.16
Amitrol + simazine	4+4	500	4.8	4.8	8300	30.0a	1.92
Amitrol + simazine	4+4	—	5.0	4.8	9300	22.7a	1.74
Simazine	4	—	5.3	2.0	8400	22.4a	0.88
Dalapon	8	—	4.8	8.8	10700	5.4b	2.44
Dalapon + amitrol	4+4	—	6.0	8.5	11900	4.9b	5.56
Dalapon	4	500	6.3	6.5	5900	4.0b	6.31
Dalapon	4	—	4.8	7.3	8300	2.7b	2.69
Amitrol	4	—	6.0	9.0	7800	2.4b	8.87
Dalapon + amitrol	4+4	500	7.0	7.8	8200	1.8b	25.13
None	—	—	10.0	1.0	1400	0.7b	1.83

[1] 1 = no growth; 10 = maximum stand.
[2] Values adjacent to the same letter are not significantly different.

150 lb. per acre. When the corn was mature, the ears were harvested, dried, and weighed.

GRASS AND ANNUAL WEED CONTROL

Growth of the corn was greatly influenced by the degree to which grasses were killed in the various plots. In untreated areas, the corn seed germinated, but most seedlings died because of extreme competition from quackgrass, bluegrass and/or annual weeds. Corn plants that survived on these plots remained small and yellowish and seldom produced an ear. The most complete kill of quackgrass in the 1957 trial resulted from applications of simazine, dalapon and simazine, and the combination of dalapon, amitrol, and simazine. Plots receiving these treatments were nearly free of new growth of grass during the summer months. The corn grew well on plots where the quackgrass was killed and annual weeds controlled, even though a heavy litter remained on the soil.

The top growth of grass was killed to the soil level on plots treated with amitrol in 1957, but regrowth appeared rapidly. By midsummer the plots were covered with a new growth of grass foliage, and in addition, heavy stands of annual weeds had developed in many plots (Table 1). Control of quackgrass and annual weeds was somewhat better on plots treated with dalapon or with dalapon and amitrol, but the control was not equal to that obtained on plots that had been treated with simazine or a combination containing simazine.

By late fall of 1957 some regrowth of quackgrass was present on plots given even the most effective treatments. By spring of

FIG. 1. Plots from the 1958 trial at Madison; left, treated with simazine and dalapon at 4 + 4 lb. per acre; right foreground, untreated.

TABLE 2.—GRASS STAND AND CORN GROWTH ON PLOTS AT STORR'S LAKE IN 1958

Chemical Treatment May 10, 1958	Rate (pounds per acre)	Grass Stand Index[1] August 27, 1958	Corn Stand (plants per acre)	Corn Yield (bushels per acre)	Cost (dollars per bushel)
Dalapon	8	6.0	7,000	8.5	2.17
Simazine	8	0.3	12,400	57.3	0.76
Dalapon + simazine	4+4	2.5	13,300	57.2	0.54
None	—	10.0	0	—	—

[1] Index 0 = no growth; 10 = maximum stand.

1958 this growth had spread considerably. After treatment with dalapon and simazine in the spring of 1958, quackgrass was killed, and virtually none was present on these plots in the fall of 1958 (Fig. 1).

Bluegrass was nearly eradicated by the simazine treatment in the 1958 trial at Storr's Lake (Table 2 and Fig. 2). The dalapon and simazine combination was fairly successful, while dalapon alone was the least effective of the three applications used.

Growth of annual weeds was very limited on all plots treated with simazine or combinations including simazine. Annual weeds were prevalent on plots treated with amitrol in the 1957 trial, and this probably reduced the growth of corn on these plots (Table 1). Plots treated with dalapon did not have many annual grassy weeds, but in some cases annual broadleaved weeds were numerous. No annual weeds developed in 1958 on the plots at Storr's Lake, even on those treated with dalapon, probably because of unusually heavy litter present on the soil surface. In every case untreated plots had very few annual weeds because of the heavy growth of sod grasses.

FIG. 2. Plots from the 1958 trial at Storr's Lake; left, treated with simazine at 8 lb. per acre; right foreground, untreated plot.

CORN YIELDS

Corn yields varied widely among plots given the different treatments in the 1957 trial at Madison (Table 1). Large differences between yields of corn are required to show significance in this trial. The large experimental error was due to considerable variation in stands of corn on the various plots following damage by rodents. Plots that had received no treatment gave virtually no yield of corn. All plots treated with simazine, either alone or in combination, gave at least a fair yield. Plots not treated with simazine gave low yields of grain in every case. The application of fertilizer appeared to be beneficial in the case of plots where adequate weed control was obtained. The application of fertilizer was clearly of no value on plots where the growth of quackgrass or annual weeds was not controlled.

The data obtained in 1958 from the plots at Madison showed that retreatment in early spring was necessary if areas were replanted (Table 3). The improved yields from the April treatment are believed to result from both the early date of application and to the inclusion of dalapon in the mixture. The data from the 1957 trial (Table 1) indicate that early-season treatments with the combination of dalapon and simazine may be preferable to the use of simazine alone. In 1958, as in 1957, the plots that received no treatment gave little or no yield.

TABLE 3.—CORN STANDS AND YIELDS ON PLOTS REPLANTED AT MADISON IN 1958

Chemical Treatment and Date of Application	Rate (pounds per acre)	Corn Stand (plants per acre)	Corn Yield (bushels per acre)	Cost (dollars per bushel)
Dalapon + simazine April 18, 1959	4+4	16,000	42.0	0.73
Simazine June 9, 1959	4	7,801	8.0	3.12
None	—	1,073	0.0	—

COST OF PRODUCTION

It is unlikely that corn can be produced as economically in food patches as it can in commercial areas with conventional methods. However, costs of production must be considered, for if they are unreasonably high, the practice will not be used even though technically successful. To evaluate the costs of producing corn by the use of herbicides, dalapon was assumed to cost \$1.49 per pound; simazine \$4.60 per pound; amitrol, \$5.00 per pound; 10–10–10 fertilizer, \$72.00 per ton; and ammonium nitrate was priced at \$87.50 per ton. The seed corn cost \$9.60 per bushel, and since about 8 lb. would be used to plant an acre, the cost per acre would be \$1.28. No costs were calculated for labor involved in applying herbicides and fertilizer or for planting the corn. It is believed that in routine practice these costs would not be more than a few dollars per acre, but no figures are available to establish this point. No charge was calculated for land rental for it is unlikely that this cost would be of consequence in land used for wildlife conservation purposes.

The lowest costs per bushel in the 1957 trial were obtained on plots treated with simazine or with combinations of simazine and dalapon (Table 1). Several of the treatments had costs approximating \$1.00 per bushel. This is possibly 50 percent higher than the cost of producing corn on cultivated land but may not be unreasonable when used for wildlife food supplies. Plots receiving fertilizer yielded substantially more than did those that were not fertilized, but the cost per bushel of corn produced was about the same on both areas.

In the 1953 trial at Storr's Lake the plots treated with the combination of simazine and dalapon produced corn at a cost of only \$0.54 per bushel (Table 2). This low cost was because of relatively high yields obtained and of the reduced cost for fertilizer. Fertilizer costs were low because ammonium nitrate rather than a complete fertilizer was used to supply nitrogen.

DISCUSSION

Hamilton and Buchholtz (1953) described chemical applications that controlled annual weeds in corn planted on tilled land free of perennial weeds. Their findings did not have wide application for establishing food patches because many areas desirable for such use are infested with quackgrass and other sod-forming perennial grasses. Thompson and Kabat (1956) and Zorb, *et al.* (1956) described studies in which dalapon was used to kill perennial grasses. Residues of dalapon in the soil are toxic to corn. According to Buchholtz and Peterson (1959) dalapon must be applied 4 weeks or more prior to planting corn in order to avoid injury to the crop. An early application of dalapon does not control annual weeds effectively during the growing season. As a result, annual weeds may seriously reduce corn yields even though the sod is killed.

In these studies the use of simazine, alone or in combination with dalapon, provided good control of the grass sod and the residue of the simazine controlled annual weeds during the growing season. In order to secure satisfactory control of quackgrass with simazine, applications should be made a month or more in advance of corn planting, because the killing action is slow. Applications made at time of planting allowed grasses to remain highly competitive while the corn was in the seedling stage.

Corn stands in the 1957 trial at Madison

were variable. This was due in part to competition from grasses and from annual weeds. Very few plants became established in the check plots. Striped spermophiles (*Citellus tridecemlineatus*) also did serious damage to the stands of corn. The germinating corn seeds were dug up and excavation continued until the surviving corn plants were about 4 in. tall. As soon as the damage was noted, attempts were made to poison the spermophiles with strychnine-coated grain. The poisoning program was only partially successful. If damage from rodents is likely, the poisoning program should be initiated in early spring several weeks before planting the corn, when burrows and runways of the rodents are easily found. Poisoned grain was distributed early in the season in the 1958 trial at Madison, and no difficulty from rodent damage was experienced. A trial in 1958 was abandoned because of damage done by tree squirrels (*Sciurus niger* and S. *carolinensis*). In this trial the damage occurred after the ears had developed kernels that were in the milk stage. The squirrels stripped the husks from most of the ears and consumed the young grain.

The most satisfactory procedure for establishing corn for food patches in sodded areas without tillage appears to involve treatment of suitable areas with simazine at the rate of 4 lb. per acre or with combinations of simazine and dalapon at 4 + 4 lb. per acre, in early spring. In areas that are flooded in early spring, application of the chemicals could be made during late fall months. The chemicals could be applied by hand sprayer, by sprayer mounted on bicycle wheels, or by power sprayer. If strips are treated, they should be at least 2 ft. wide in order to reduce encroachment upon the corn by adjacent vegetation. If rodents are present, they should be controlled during early spring when their burrows and runways are easily seen. The food patch should be located 200 yds. or more from timbered areas to reduce the possibility of damage from tree squirrels.

If the soil in the area is known to be deficient in potassium, phosphorus or nitrogen, an application of a fertilizer of the proper analysis will increase yields of grain. Nutrients released from roots, rhizomes, and litter of killed grasses may be sufficient for a reasonble yield of corn the first year but probably will not allow maximum yields. Nitrogen is likely to be limiting for corn growth during the early part of the season because decomposition of grass roots and rhizomes will cause the nitrogen supply in the soil to be unavailable to the corn. Fertilizer applications can be made by hand or by calibrated equipment before or immediately after planting.

Hybrid-seed corn will be most productive, and a strain that is relatively early in maturity should be used in order to ensure the production of ripe grain. Plant stands might vary from 10,000 to as many as 20,000 plants per acre depending on the productivity of the area. In small areas planting might be done by hand as easily as by machine. If a machine is used, it should be equipped with a rolling coulter in front of the planter shoe to cut through the sod. A press wheel behind the shoe is required to firm the soil around the planted seed. After planting, no further attenion should be required. A few weedy plants may develop in the area, but these should not reduce the corn growth and may increase the cover available in the area. Food patches should be fenced to avoid damage from livestock. In more remote areas deer damage may be a problem.

Selection of sites with soils that have a relatively high native fertility and a favorable moisture-retaining capacity should favor production of moderate to high yields of corn. In such areas applications of fertilizer might be limited to moderate rates of ammonium nitrate or other materials supplying nitrogen. Locating the food patches on favorable sites will make economical production of corn much more certain.

Established food patches should be satisfactory for replanting for several years. Areas to be replanted must be retreated with simazine in early spring of each year to control annual weeds and maintain control of

perennial grasses. No tillage is required, and the corn is planted through the litter of the previous year. Applications of fertilizer will be helpful in maintaining satisfactory yields of grain when areas are replanted.

SUMMARY

Satisfactory yields of corn were produced on sodded areas without tillage after applications of simazine or combinations of dalapon and simazine. Applications of dalapon and amitrol, alone or in combination, were less satisfactory for control of perennial grasses, and control of annual weeds was also poor. Applications of simazine were most effective when made in early spring. Dalapon or a combination treatment containing dalapon must be applied at least 4 weeks prior to corn planting in order to avoid injury to the corn. Use of a complete fertilizer increased yields of corn appreciably in one study but did not result in more economical production of corn. Cost for chemicals and fertilizer when using the more satisfactory treatments averaged about $1.00 per bushel, and in one instance was as low as $0.54 a bushel. Use of herbicides in the manner described will allow production of corn in remote areas for wildlife purposes, without the use of heavy mechanical equipment, and without attention after the planting has been completed.

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OBITUARIES

ALVA W. BLACKERBY

1909–1959

Alva W. Blackerby, supervisor of the Nez Perce National Forest, died August 22, 1959, from injuries received in an airplane accident on August 4. A Ford trimotor plane crashed while landing at the Forest Service Moose Creek landing strip, Nez Perce National Forest, Idaho.

Blackie, as he was known to his friends, had a genuine interest in wildlife conservation and had joined The Wildlife Society shortly after being assigned to the Nez Perce National Forest in March of 1957.

Born April 27, 1909, in Wapinitia, Oregon, Blackie graduated from the University of Oregon in 1937 with a B.S. in education and received the M.S. in forestry from Oregon State College in 1939. He worked summers for the Forest Service from 1928 to 1939 and in 1939 entered the U.S. Forest Service at Juneau, Alaska, as an educational advisor in the Civilian Conservation Corps. He served as administrative assistant, and later as deputy fiscal agent in charge of personnel management in the Juneau regional office. For 3 years he was in charge of the Admiralty Division of the Tongass National Forest, responsible for the planning and direction of the administrative activities for the protection, utilization, and development of timber, wildlife, recreation, and watershed. He was transferred to the Kaniksu National Forest in northern Idaho in 1955 as assistant forest supervisor and reassigned on March 3, 1957, as forest supervisor of the Nez Perce National Forest, which position he held at the time of his death.—PAUL D. DALKE

ALBERT L. STEELE, JR.

1916–1959

Albert L. (Jack) Steele, Jr., Wildlife Biologist for the Texas Game and Fish Commission, died of a coronary occlusion at Lufkin, Texas, on July 1, 1959.

Jack was born in Madisonville, Texas, on April 27, 1916. He received a B.S. degree in wildlife management from Texas Agricultural and Mechanical College in 1949, and was employed at that time as a wildlife biologist by the Texas Game and Fish Commission.

During World War II, Jack served in the infantry from 1942 to 1945. He saw combat service in Europe and was wounded in action in Germany.

His primary interests in game management work were in the field of deer and turkey investigations and development work. Texas recently adopted a standard procedure for making deer-track counts. This method was based largely on Jack's experience in this field since he had the earliest and most comprehensive records on this activity in the state. A restocking project with turkeys from South Carolina was one of his last and most difficult assignments. Recent reports indicate this plant may become the first successful restocking of the eastern turkey in the western edge of the former range in Texas.

Jack was well liked and made friends easily both within and outside of his chosen profession. In addition to his sound professional accomplishments, he will be remembered for his humor and his friendly nature.

He is survived by his wife Doris, his mother, Mrs. A. L. Steele of Houston, and a brother, Dr. F. B. Steele of Vernon, Texas.—Daniel W. Lay

BRIEFER ARTICLES

WOODCOCK REPRODUCTION IN DDT-SPRAYED AREAS OF NEW BRUNSWICK

Bruce S. Wright

Northeastern Wildlife Station, University of New Brunswick, Fredericton, New Brunswick

Chlorinated hydrocarbon pesticides (and some others) have a drastic effect on the reproduction of quail and pheasants under laboratory conditions (DeWitt, 1955, 1956; DeWitt, *et al.*, 1955). Even minute quantities in the diet of adult birds reduced the number of chicks produced, and increased percentages of crippled and defective chicks. Young birds from these experimental groups were highly susceptible to the test compounds, and few, if any, survived when fed at levels which permitted survival of chicks from normal (undosed) parents.

This paper presents observations on the proportion of young woodcock (*Philohela minor*) in samples taken from sprayed and unsprayed areas of New Brunswick which indicate that similar toxic effects may have been caused in woodcock by the continued spraying of breeding grounds with DDT for spruce budworm control.

The sample birds were collected by cooperators and staff of the Northeastern Wildlife Station. Sex and age determinations of the 1959 birds were made by the Section of Population and Distribution Studies of the Bureau of Sport Fisheries and Wildlife of the U.S. Fish and Wildlife Service. Most of the collecting was done in the Tobique Valley, but birds were collected as opportunity afforded in all parts of the sprayed zone. This area covers the greater part of New Brunswick north of the Miramichi River.

Spray Program

The New Brunswick spruce budworm control program has been described in detail by Webb (1959). The spray program and the schedule of woodcock collecting are shown in Tables 1 and 2. The dosage used was usually ½ lb. of DDT per acre, but some areas received 1 lb. of DDT per acre in the first year of the operation. The whole area was sprayed once, but most of it was resprayed from one to five times from 1952 through 1958.

Woodcock Sample

A total of 105 woodcock were collected in the sprayed area, and 660 were collected in the unsprayed areas in the period 1953 through 1958. All birds were collected between September 20 and November 4. They were aged by primary wear following Sheldon, *et al.* (1958), and sexed by primary width following Greeley (1953).

Results

The proportion of young in the fall bag is shown in Table 2. The statistical significance of these results was tested by the chi-square test (Snedecor, 1956). The results showed a highly significant dif-

Table 1.—Spray Program for Spruce Budworm Control in New Brunswick

Year	Area Sprayed or Resprayed (square miles)
1952	300
1953	2,800
1954	1,800
1955	1,800
1956	3,100
1957	8,100
1958	4,100
Total	22,000

TABLE 2.—COMPARISON OF YOUNG WOODCOCK IN THE FALL BAG IN THE SPRAYED AND UNSPRAYED AREAS OF NEW BRUNSWICK

Year	Sample		Percentage Immature	
	Sprayed	Unsprayed	Sprayed	Unsprayed
1953[1]	19	50	37	44
1954	12	62	17	50
1955	14	27	21	52
1958	60	512	20	45
Total	105	660		
Mean			23	45

[1] Since spraying took place in June 1953 after the hatch was off, this year can be taken as unsprayed for purposes of comparison.

ference between sprayed and unsprayed areas in 1958 after the area had been sprayed or resprayed up to five times. The totals of all years' spray on the ground also showed a highly significant difference between the sprayed and unsprayed areas.

All data indicated a decrease in the proportion of young in the sprayed area. The decrease was of a highly significant level in both comparisons made with the total sample of the areas for which a reasonably large sample of birds were available. The trend of every measurement was in the same direction.

In 1959, 65 of 856 woodcock collected were from the spray zone as it is the least hunted and most inaccessible. The remainder came from unsprayed areas to the south and southwest. No spraying was done in 1959, so that the area represented the condition 1 year after spraying and respraying for 6 years had ceased.

Table 3 compares the proportion of young in the fall bag in and out of the spray zone in 1959 with conditions in 1958, the last year of spraying. In 1958 there was only 20 percent young in the sprayed area. In 1959, a year after spraying ceased, there was 49 percent young in this area. This is an increase of 145 percent in a year when young in two unsprayed control areas increased only 31 and 33 percent respectively. This difference suggests that breeding success may have been materially affected by the successive sprayings the area had been subjected to, and as the 49 percent young in the sprayed area was still below the 59 percent and 64 percent in the unsprayed areas that year, it indicates that the sprayed area had not completely recovered from spray effects in one year.

TABLE 3.—COMPARISON OF YOUNG WOODCOCK IN THE FALL BAGS FROM THE SPRAYED AND UNSPRAYED AREAS OF NEW BRUNSWICK, 1958–59

Zone	Year	Sample	Percentage Immature	Percentage Increase
Unsprayed				
Central	1958	521	45	
	1959	545	59	31
Southern	1958	115	48	
	1959	246	64	33
Sprayed				
Northern	1958	60	20	
	1959	65	49	145

DISCUSSION

This note describes observations of the proportion of young birds in a sample of the population, but does not represent a systematic determination of the effect of pesticides upon the reproduction of woodcock. It does not establish that these differences are typical of the populations, or that they are attributable to effects of the pesticide. It reports a phenomenon that has occurred and has been measured by the only method available. The 1960 plans for the budworm spray call for an additional 2½ million acres of the much more accessible central zone to be sprayed. This zone contains a much higher density of breeding woodcock than the northern zone, and it is heavily hunted. The study will be continued in this area.

In 1959, a further complication was added. A sample of 10 woodcock collected in New Brunswick in June was analyzed by the Section of Chemical, Physiological, and Pesticide–Wildlife Studies of the U.S. Fish and Wildlife Service. They were found to contain 0.18 p.p.m. of heptachlor epoxide, proving that they had been exposed to heptachlor during their stay on the winter range. This was presumably the heptachlor application of the U.S. Department of Agriculture's fire ant eradication program in the southeastern states where banding returns show birds from this region winter. Thus New Brunswick woodcock are now shown to be exposed to pesticide poisoning at both ends of their migratory range.

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SEASONAL CHANGES IN THYROID GLAND MORPHOLOGY OF MALE GRAY SQUIRRELS[1]

Roger A. Hoffman and Charles M. Kirkpatrick

Physiology Division, Army Chemical Center. Edgewood, Maryland; and Purdue University Agricultural Experiment Station, Lafayette, Indiana

In a previous paper (Kirkpatrick and Hoffman, 1960), we presented data indicating that male gray squirrels (*Sciurus carolinensis*) attain sexual maturity at about 10–11 months of age. Males from spring litters remain sexually active longer than those from summer litters. Following a period of sexual activity of 3–8 months, all males enter a period of sexual decline in the summer, reaching a quiescent stage characterized by non-functional reproductive organs. Approximately 2 months later (October), sexual redevelopment begins, marked by reenlargement of organs and new proliferation of germinal and secretory epithelium (Kirkpatrick, 1955; Mossman, *et al.*, 1955). The period of adult redevelopment coincides with initial development of spring juveniles resulting, in December, in a general primeness of all but summer-born males. Hence, it appears that initial sexual development is age-connected, in part, but redevelcpment must have another stimulus. Body weight is not important as an indicator of the physical conditioning required for sexual development (Kirkpatrick and Hoffman, 1960).

Further studies, undertaken to ascertain the hormonal or environmental factors which might influence sexual activity, provide the data presented here. The purpose of this paper is to consider the thyroid gland of male squirrels in connection with changes in their sexual activity or ages, and as related to seasons.

The influence of the thyroid gland on reproductive processes has long been recognized and recently reviewed by Maqsood (1952). As a general rule, increased cell height is directly correlated with increased thyroid gland function. For the present study, thyroid cell height was measured in male gray squirrels collected each month, comprising two ages and various sexual development classifications. Other studies are now in progress relating to adrenal, thymus and pituitary changes.

Materials and Methods

A total of 201 male gray squirrels supplied the data for this study. One hundred and twenty of these were collected within a single year, and tissue preparations and data from additional animals were available from previous collections.

Thyroid and reproductive glands were removed, divested of extraneous tissue, and fixed in AFA fixative. The fixed glands were weighed to the nearest 0.1 mg. on a Roller-Smith torsion balance. The tissues were embedded in paraffin, sectioned at 6–8 μ and stained by the method of Groat (Hoffman, 1952) or Masson's trichrome stain. The animals were classified according to the sexual development classes previously described (Hoffman and Kirkpatrick, 1956).

The thyroid glands were serially sectioned and representative samples from the first, middle, and last thirds were projected onto a white screen with a carbon-arc micro-projector at a magnification of 1000 diameters. A total of 80–100 epithelial cells were measured for the mean cell height of each individual. Monthly and 2-month means were obtained and standard errors of the means were calculated by the method of Tippet (1925).

Results

The classification of these animals and their distribution by months are included in Table 1 in our previous paper (Kirkpatrick and Hoffman, 1960) and will not be discussed here.

The thyroid glands of gray squirrels did not appear to differ appreciably from those of other typical mammals, either grossly or microscopically. Within a monthly sample and throughout the year, the color varied considerably from a light or pale pink to dark brown. Presumably, these color variations reflected the vascularity at the time of sacrifice, the amount of colloid storage and iodine content. A predominant number of thyroid glands had parathyroid tissue closely attached peripherally or almost completely embedded in the thyroid tissue. Usually, the thyroid epithelial nuclei were basally located within the epithelial cells, but when nuclei were occasionally found in the middle or at the apical end of the cell, vacuoles were frequently seen at the basal end. Vacuolation did not seem to be associated with any particular season, age, or stage of sexual activity, and apparently is only transitory since few glands exhibited it.

Any measurement from a population containing animals from both age classes and different stages of sexual development must be considered in light of these somatic and physiological differences. Since age, season, and sexual development are all factors which could influence the weight and cell height of the thyroid gland, the data obtained were handled in such a way that the individual effect of each of these variables alone was being measured.

If we disregard for the moment the influence of season, both the relative weight and cell height of the thyroid gland was maximal in the infantile animal (Table 1). The values were smaller in the prepubertal class, suggesting that reproductive de-

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velopment, superimposed on the demands of somatic growth and development (Kirkpatrick and Barnett, 1957), does not result in morphological changes in the thyroid gland indicative of increased activity. A further decline in cell height and thyroid gland weight was evident in the three classes of adults. In these groups, where somatic growth had ceased, minimal cell height was evident in the degenerating class. However, when thyroid cell height of this group was compared with the functional or redeveloping classes only in the months when both of these classes occurred in the population, no significant differences were found. Thus, once adulthood is reached, thyroid gland morphology and function remain at a certain level of activity regardless of changes in reproductive activity.

Further inspection of the data (Table 1) revealed that the weight and cell height of the thyroid glands of all juvenile animals were significantly greater than those of all adults. Again, assuming that these measurements are indicative of the level of thyroid gland function, we conclude that a high level of activity of this endocrine gland is associated with somatic growth and development. Once these processes cease, the thyroid gland operates at a lower level of activity or function.

When the mean weight and mean cell height of all thyroid glands were considered as a function of season, maximal relative weight (mg./100 gm. of body weight) occurred in October–November, and the minimum occurred in the period of March through August 1 (Fig. 1). Maximal cell height was associated with the peak in thyroid weight. Minimal cell height occurred in June during the period of low-level activity. The weight curve declined more rapidly than the cell-height curve after October–November, suggesting that rapid colloid depletion was taking place in addition to a decrease in height of epithelial cells.

To emphasize the effect of season alone, and to eliminate the influence of somatic and sexual development, mean thyroid cell height of a single stage of sexual development was plotted as a function of season (Fig. 2). Functional animals were

TABLE 1.—MEAN THYROID GLAND WEIGHT AND CELL HEIGHT FOR ALL MONTHS IN THE FIVE CLASSES OF SEXUAL DEVELOPMENT IN MALE GRAY SQUIRRELS

Sexual Development Class	Thyroid Weight (mg. percent and S.E.)	Thyroid Cell Height (microns and S.E.)
JUVENILES	6.1±0.2 (52)[1]	7.12±0.10 (64)[1]
Infantile	6.2±0.3 (35)	7.26±0.12 (40)
Prepubertal	6.0±0.4 (17)	6.90±0.14 (24)
ADULTS	5.5±0.1 (110)	6.58±0.05 (137)
Functional	5.6±0.2 (76)	6.48±0.09 (93)
Degenerating	5.1±0.3 (19)	6.78±0.17 (22)
Redeveloping	5.3±0.4 (15)	6.83±0.21 (22)
Total	162	201

[1] Numbers of animals providing data shown in parentheses.

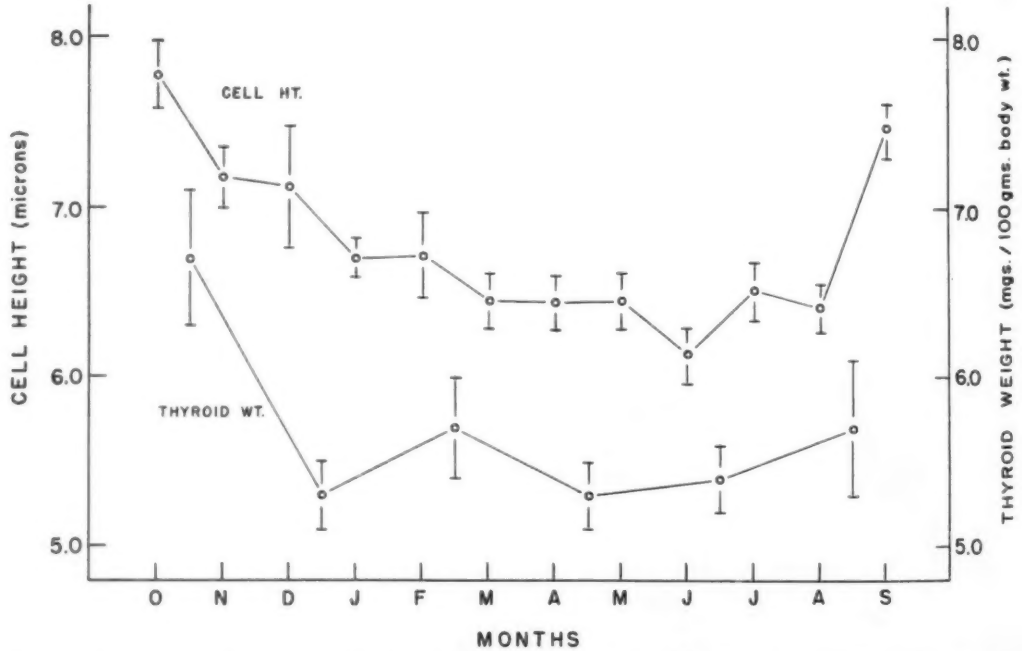

FIG. 1. Seasonal changes in mean weight and cell height of thyroid glands in male gray squirrels. Both age classes and all stages of sexual development are included.

chosen since theirs was the predominant class and they were found in 11 of the 12 months. Furthermore, this group might be considered as somewhat comparable to a continuous breeder such as the white rat. These data also show that thyroid gland cell height fluctuates under seasonal influences. No modifications are apparent during the two periods of maximal breeding activity which have been noted by various investigators (Kirkpatrick and Hoffman, 1960). Rather, cell height undergoes regular and gradual changes, seemingly under separate regulation and irrespective of the gonad cycle.

Thyroid glands from female gray squirrels collected simultaneously with the males were measured for comparison of cell height during two of the periods. When figures for animals of all ages and sexual activity were averaged, little difference existed between males and females (December–January—males, $7.02 \pm 0.10 \mu$ vs. females, $6.60 \pm 0.12 \mu$; August–September—males, $6.96 \pm 0.14 \mu$ vs. females, $6.60 \pm 0.12 \mu$).

DISCUSSION

Periods of sexual activity in the male gray squirrel were not accompanied by morphometric evidence of increased thyroid gland function. Rather, a seasonally cyclic rhythm in weight and cellular activity was evident, regulated by unknown factors.

A considerable body of literature exists indicating that thyroid gland activity and morphology of various mammalian species fluctuates in response to changing seasonal influence (Adams, 1946; Tala, 1952; Hoffman and Zarrow, 1958). Our data show that the gray squirrel may also be added to this list. The period of maximal cell height appears to differ with each species. Minimal cell height in squirrels is not as distinct as the maximal period, but, similar to that in other species (Tala, 1952), extends over several months. Undoubtedly, thyroid gland activity is adjusted to operate at the necessary level to maintain a state of physiological equilibrium under changing metabolic demands.

It is difficult to correlate the periods of maximal and minimal thyroid gland activity specifically with any particular environmental factor. It is known that thyroid gland function of homeotherms increases following acute exposure to cold while a depressed activity is evident when animals are subjected to warmer temperatures.

Our data show that thyroid cell height increased after the months of June–July, correlating with the decreasing temperatures which became evident at this time. However, maximal activity is found in September–October followed by a prolonged decline to the minimum in June–July. Thus, both the increase and decrease occur under conditions of decreasing temperature. If temperature is possibly the primary regulator of the thyroid gland, perhaps its function is modified by other factors, e.g., gonadal hormones. Pertinent to this is a de-

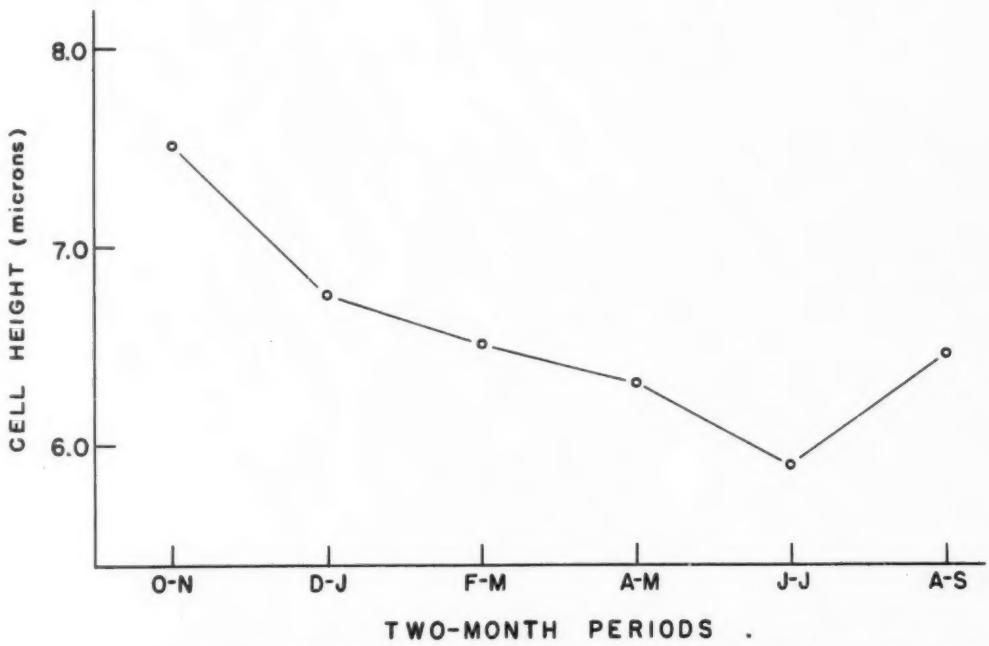

FIG. 2. Seasonal changes in cell height of thyroid glands in male gray squirrels in the functional stage of sexual development.

pressant effect of estrogens on thyroid gland activity in rats (Farbmann, 1944; Koenig, *et al.*, 1945).

While light might have a stimulatory or inhibitory effect on thyroid activity, the available information as to its effect in mammalian species has been controversial (Puntriano and Meites, 1951; Maqsood, 1952). Also, a correlation of thyroid cell height and light has not been found in our data from male gray squirrels. On the other hand, we have pointed out that both estrous periods of the female usually occur under conditions of increasing light (Hoffman and Kirkpatrick, unpubl. ms.).

Diet may influence the weight and physiological function of the thyroid glands of squirrels. A diet low in iodine would be expected to result in a stimulation of thyroid function leading to an increased weight and cell height. Although the seasonal spectrum of iodine in squirrel foods is unknown, nuts and cereal grains are low in iodine content (McClendon, 1939:34). In this Indiana area, mast is generally abundant from August through early winter. It is assumed that mast forms a major portion of the diet during this period which also encompasses both the peak and decline of thyroid cell height and weight. If mast is generally low in iodine and produces a compensatory thyroid activity, the reason for the thyroid decline is obscure.

Again, no correlation seems to exist in the low cell height and weight values during late winter and early spring, when residual mast often is available and cereal grains are found at feeding stations patronized by local squirrels. During this period also, the diet is varied with buds and green seeds (Brown and Yeager, 1945), which, by inference from green plants (McClendon, 1939:34), may contain higher proportions of iodine than nuts and grain. Thus, the available evidence is suggestive, but by no means clear-cut, that diet plays an important part in the thyroid activity of squirrels.

As suggested by the above discussion, the regulation of thyroid gland activity in gray squirrels is not clearly understood. Undoubtedly, a combination of changing environmental factors, plus a complex interaction of various endocrine secretions, act to produce characteristic levels of activity. Investigations in other species have shown seasonal changes in thyroid gland morphology in spite of constant conditions of light and temperature (Tala, 1952; Hoffman and Zarrow, 1958).

The data of Table 1 and Fig. 2 show that thyroid gland cell height fluctuates with season and age but not in relation to sexual activity. Higher levels of thyroid gland activity are apparent in the physically immature animals, suggesting a higher metabolic activity associated with somatic growth and development and presumably a greater utilization of thyroid hormone. This higher level of thyroid activity in the young has been previously demonstrated in several species including mice (Jacobs, 1958) and rats (Grad and Hoffman, 1955).

It is noteworthy that sexual degeneration occurs during the summer months, the period of low thyroid activity. This sexual degeneration is found in *all* males regardless of age or duration of sexual activity. These observations, plus the recognition that administration of thyroid hormones can increase reproductive vigor of many animals during the warm summer months (see review by Maqsood, 1952), led us to suggest previously that the thyroid gland conceivably regulates the reproductive cycle in squirrels. Our general hypothesis, developed inferentially from thyroid cellular morphology, is that: (1) the thyroid secretion, during summer months, is inadequate to support a reproductive state, and a period of sexual quiescence ensues in both sexes; (2) coincident with maximal thyroid activity in the fall, males and females of adequate age and physical condition begin to show signs of sexual stimulation culminating in a period of full sexual activity; (3) litters are born at times such that weanlings become independent during climatic conditions favorable for their survival. Experimental work is probably necessary to test the validity of this hypothesis.

SUMMARY

The weight and morphology of thyroid glands from male gray squirrels change in relation to season and age but not with sexual activity. A greater thyroid activity in juvenile animals was associated with somatic development. In all classes of sexual development and within a single class (functional), minimal activity occurred in June–July and maximal activity in October–November. No obvious correlation existed between the seasonal changes in thyroid gland morphology and the environmental factors of light, temperature, and food. It was suggested that the thyroid cycle is influenced by external environmental factors, modified perhaps by unknown internal factors. Declining reproduction of gray squirrels during the warm summer months is believed to be related to low thyroid gland activity.

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SMOKELESS POWDER CANNON WITH LIGHTWEIGHT NETTING FOR TRAPPING GEESE[1]

Richard E. Marquardt

Oklahoma State University, Stillwater, Oklahoma[2]

A goose trapping program initiated in tall-grass prairie regions of Oklahoma and Texas in 1957 encountered numerous setbacks as a result of malfunctions and other inadequacies of the projectile net equipment. The projectile equipment used was essentially that of Dill and Thornsberry (J. Wildl. Mgmt., 14(2):132–137, 1950), with modifications described in the U.S. Fish and Wildlife Service manual, *Guide to Waterfowl Banding* (Patuxent Research Refuge, Section 2111, Figure 38, 1956). The recommended propellant for this assembly is black powder, usually grade FFG.

Lake shore situations suitable for permanent trapping sites were not available. Therefore, practically all trapping efforts were conducted in open-field situations where there was little or no gradient at the trapping site and opportunities for concealment of the equipment were relatively slight. Soils ranged from light sand to subsurface rock.

As a result of repeated failures to meet the requirements imposed by the varied trapping conditions encountered during the 1957–58 season, several inadequacies in the design and components of this equipment became readily apparent. In rainy weather, the recommended short cannon holders allowed considerable leakage of moisture, and wet charges from this cause were a constant problem. Because of its hygroscopic nature, black powder left in the cannon for some time resulted in damp charges even though precipitation did not occur. Further, the residue from these charges, which is also hygroscopic, is difficult to remove from a closed-breech bore in the field without an undue amount of equipment and expenditure of time. Consequently, rust and pitting in breech and barrels of cannon using this propellant is a common occurrence and one which necessitates constant maintenance.

The problem of leakage could be reduced by merely increasing the length of the cannon holder. However, the other problems could only be resolved by turning to a less hygroscopic, cleaner-burning propellant. It was also felt that any reduction in the number of parts or in the overall size of the units would be an asset in field use. Accordingly, a series of tests using bulk smokeless powder and modified equipment were conducted. The test assemblies were constructed by Bollinger Machine Works, Stillwater, Oklahoma.

The initial test assembly differed from that described in the *Guide to Waterfowl Banding* (1956) in having a slightly smaller bore diameter, a shorter barrel, a longer cannon holder, and a metal recoil plate which is an integral part of the cannon holder. The projectile was not grooved for Neo-

[1] Contribution of the Oklahoma Cooperative Wildlife Research Unit; Oklahoma State University, Oklahoma Department of Wildlife Conservation, Wildlife Management Institute, and U.S. Fish and Wildlife Service, cooperating. Zoology Contribution No. 295.

[2] During various phases in the testing of this equipment, assistance was rendered by L. H. Bruneau, T. A. Miller, R. J. McDaniel, and M. E. Sisk. Technical advice concerning ballistic physics was obtained from E. E. Kohnke.

prene rings, but was machined and polished to 0.002 in. clearance with the barrel. This assembly began to fail with continued firing of moderate smokeless powder loads of 50 grains (3.25 grams) and failed completely with the heavier loads of 75 grains (4.87 grams).

On the basis of this experience, two changes were made in the second unit, namely, a heavier recoil plate and a new breech design. An inverted cone with 45° shoulders was machined into the inside face of the breech block to increase the firing-chamber volume and thereby reduce pressures. The sloping shoulders of this new breech also tend to reduce the sidewall thrust of the explosion by directing the force at an oblique angle to the bore at the breech face. As a consequence of increasing the firing-chamber volume, it was necessary to increase the powder charge to obtain desirable velocities. This second design proved adequate in the tests and two units were built for use with a small net. Details of the breech design are given in Fig. 1.

The barrel of the cannon is a 15¾-in. length of 11-guage-wall seamless tubing with an inside diameter of 2⅜ in. The breech is a 3-in. length of 2⅝-in. round cold-rolled stock, turned down to 2⅜ in. 1 inch from the inside face and bored through the center for a 1¹³⁄₁₆-in. shell chamber. An inverted cone with 45° shoulders is machined to a depth of ⅝ in. into the breech face. A ⅛-in. rim of the original breech face supports the projectile. The rear of the shell chamber is counterbored 1¼₁₆ in. × 1/32 in. for the shell rim. An extractor groove is optional. The projectile is a piece of round, cold-rolled steel stock, 3¾ in. × 2⅜ – 0.002 in., polished, with a ⅜-in. chain link welded to one face. The weight is approximately 5 pounds. The cannon holder is a 16¾-in. length of 11-guage-wall welded tubing with an inside diameter of 2⅞ in. The recoil plate is a steel plate, ½ in. × 6 in. × 12 in., to which the cannon holder is welded at the center. A ⅜-in. × 10-in. steel rod, bent to form a handle and welded to the cannon holder, facilitates carrying of the complete unit.

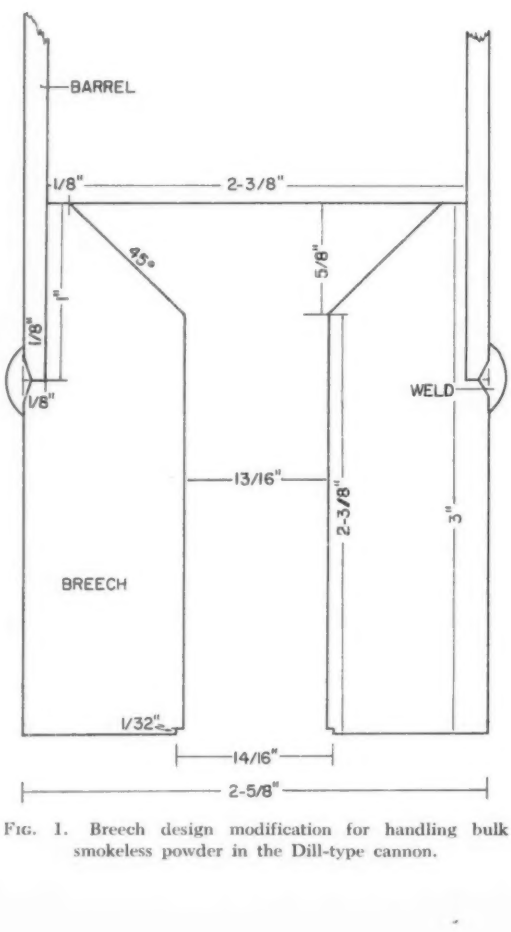

FIG. 1. Breech design modification for handling bulk smokeless powder in the Dill-type cannon.

Results of the tests are summarized in Table 1. The black powder tests were used as controls against which the smokeless powder loads could be compared. It was of interest that even in the short-barreled cannon, combustion of the black powder was complete. The velocity data presented are calculated from the formula

$$R = V_{ox}(2t) = \frac{2V_o^2 \cos \phi \sin \phi}{g}$$

and are therefore approximate, but nonetheless of value in judging the relative merits of the charges and breech designs. Tests in the new assembly were concluded at 75 grains of bulk smokeless powder. Although it is believed that much higher velocities can be obtained with this unit, it was not considered necessary or practical to exceed those produced by black powder. The problem of efficient net projection is one not only of projectile velocities, but also small inertia in terms of weight and air resistance of the net.

Three detonators were used in the firing tests, namely, the Hercules No. 6 blasting cap, the Hercules waterproof squib, and the Atlas squib. In the larger chamber of the new breech design, the Hercules squib proved most satisfactory. The Atlas squib was inadequate for complete combustion and the No. 6 blasting cap proved overly powerful, giving higher pressures in addition to being somewhat more sensitive and dangerous to handle. The propellant containers were fashioned from 12-gauge shotshells with the primer pockets reamed out to admit the seating of the waterproof squib, then sealed with Duco cement around the primer pocket and with wax around the top powder wad.

The two cannons were teamed with a 30-ft. × 40-ft. net fashioned by lacing together 3-ft. × 40-ft. lengths of 3½-in. mesh gill netting from which the leadline and floats had been removed. The floatline was left intact. The periphery of the net was bound with a 500-pound test nylon cord. Weight of the net, complete with four anchor lines,

TABLE 1.—MUZZLE VELOCITY AND ENERGY FOR EXPERIMENTAL LOADS IN DILL-TYPE CANNON

Test Loads	Weight of Test Loads (grains)	Average Velocity in Feet per Second	Average Energy in Foot-pounds	Remarks
Black powder, FFG	120	164	2090	Standard breech; Atlas squib; severe fouling in barrel.
Black powder, FFG	180	202	3187	Standard breech; Atlas squib; severe fouling in barrel.
Bulk smokeless	50	181	2551	Standard breech; Atlas squib; no fouling; recoil plate bending; slight swell in barrel at breech.
Bulk smokeless	75	216	3648	Standard breech; Atlas squib; no fouling; recoil plate buckled; barrel swelled at breech and burst in later test.
Bulk smokeless	75	175	2381	Modified breech; Hercules squib; light fouling in barrel, no evidence of high pressure; heavy recoil plate undamaged.

is approximately 15 pounds. The projectile cords of 1100-pound test nylon fasten to the net with harness snaps which facilitate removal of the projectiles for cleaning and refolding of the net. Drag anchors used consisted of four 5-pound window-sash weights instead of anchor stakes.

The light weight and open mesh of the nylon net reduced inertia and air resistance in projection and consequently provided for higher sustained velocity over the distance of travel. This is particularly desirable when it is necessary to fire against the wind. The rapidity of net extension practically negated escape by flying birds outdistancing the leading edge of the net, a phenomenon commonly observed when using the heavier and slower nets. Moreover, it reduced the amount of "pile-up" by the geese along the leading edge after the net had extended. However, because of the light weight and openess of the net, geese appeared to struggle longer and more intensely to escape. The birds also tangled in the large mesh, making their removal difficult and time consuming. The small diameter of the netting cord tended to cut through the skin of the wings causing unsightly, though not serious, wounds. Stretching and staking the net edges after a capture serves to alleviate this problem, but does not completely overcome it.

In operation, soil conditions permitting, the two cannons are completely buried. A sheet of Saran Wrap or a plastic bag is secured with a heavy rubber band over the openings for both the barrel and holder providing a nearly waterproof seal. A light layer of soil over the muzzle covering satisfactorily camouflages the entire unit. Combining the holder and recoil plate into one unit does away with the necessity of driving recoil stakes and is a decided advantage when the unit is used in rocky soil where driving a stake is impossible or in light, sandy soil where the stake will not support the weight of the cannon assembly. Handles attached to the holders facilitate field use in that the holder, recoil plate, barrel, and projectile can be carried as a single unit in one hand. All exterior metal parts are painted a dull ground color to reduce visibility and provide protection from rust. After two seasons' use the units remain in nearly perfect condition.

This unit was designed for open-field trapping, and therefore had to be highly efficient and yet meet the requirements of low maintenance, high portability, and ease of concealment. This places demands on equipment not normally required in lake-shore or permanent-site trapping. Thus, some workers may find this design more elaborate than is necessary to meet their needs. Moreover, where large banding crews are available and abundant numbers of geese are present, the modifications incorporated in this unit may actually be considered handicaps that cause tangling of birds in the net, superficial wounds, etc.

It is difficult to compare the efficiency of this unit with black powder cannon and conventional net units on the basis of numbers captured. The 30-ft. × 40-ft. net will capture nearly 200 geese at one shot if they are available. The largest single capture to date is 192 geese, which is equivalent to 1 goose per 6.25 sq. ft. of net. To my knowledge, this performance compares quite favorably with conventional units on lake-shore sites. However, it has not been common to have this many geese concentrated in front of the net on an open-field site. By observation, this unit, if properly handled, will capture 100 per cent of the geese within the stretched-net distance. Actually, since the net is not anchored, it will capture geese for some 10–15 feet beyond the stretched-net distance.

On the basis of 2 years' experience, the modified cannon and lightweight net have fully justified the time and expense spent on their development. The high degree of portability coupled with extreme efficiency and lack of maintenance problems make this a highly desirable piece of field equipment for net trapping.

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EARLY MORTALITY IN FUR SEALS ACCORDING TO SEX

Karl Niggol

United States Fish and Wildlife Service, Bureau of Commercial Fisheries,
Marine Mammal Research, Seattle, Washington

On the Pribilof Islands, Alaska, over 300,000 fur seals (*Callorhinus ursinus*) were tagged in the decade ending 1959. On the basis of preliminary studies (Kenyon, *et al.*, 1954), it was assumed that equal numbers of males and females were tagged. It was also assumed that the mortality rates of both sexes are equal up to age 3, at which time only 12 to 25 seals remain out of each 100 born. The data now accumulated from tag recoveries are not sufficient to prove or disprove that the mortality rates of the sexes are essentially equal up to age 3 or 4.

The writer has examined field data, mostly unpublished, obtained at sea off the west coast of North America and off Japan, and on the Pribilof Islands. The data pertain to 3,081 fetal seals taken at sea in January or later, 1952–59, and 3,648 black pups examined on land in August and September, 1950–59, within 3 months after birth. (Seals are born in greatest numbers in mid-July.)

A description of pelagic collecting methods has been given by Taylor, *et al.* (1955). The smallest fetuses available for study were taken in January. Although they had attained only ½ percent mean newborn weight, their sex was plainly shown by the presence or absence of a penial opening on the smooth surface of the belly. (Mean newborn weight for males is 5.4 kg. and for females is 4.8 kg. according to Scheffer and Wilke, 1953:133.) The sex of black pups on land in August and September was identified in four separate years during the course of routine studies on the Pribilof Islands by Fish and Wildlife Service biologists.

The present study was conceived as a search for sex disparity in fetal death rates. While no disparity was found, the results are perhaps of general interest because they shed light on fetal sex ratios in a large, wild, relatively unexploited population of mammals. (While 3- and 4-year males are heavily exploited, fewer than 5 percent of the adult females are cropped annually.) Table 1 shows that the sex ratio of fetuses did not change appreciably throughout the last 6 months of gestation, mid-January to mid-July. Douglas G. Chapman, University of Washington statistical consultant, has applied a chi-square test of homogeneity to the data for individual 10-day periods, and has reported (*in lit.*) that they are "remarkably uniform." The 95 percent confidence limits for the overall percentage of males in the fetal population is 50.89± 1.79. The percentage of males in the five subsamples (footnote to Table 1) are, respectively, 53.1, 52.7, 40.2, 52.1, and 48.9. The subsample showing males in the minority, 40.2 percent, included only 97 seals.

Postnatal sex ratios are shown in Table 2. In each of four samples, males are in the majority.

In summary, the percent males in a sample of 3,081 prenatal seals was 50.9; in 3,648 postnatal, young seals, it was 52.4; in the combined lot of 6,729, it was 51.7. No shift in mortality rate by either sex was evident during the last 6 months of gestation.

TABLE 1.—PRENATAL SEX RATIOS OF FUR SEALS, JANUARY–JULY[1]

10-day Period	Number of Fetuses			Percent Males
	Male	Female	Both	
11–20 January	1	–	1	100.0
21–30 January	32	54	86	37.2
31 January–9 February	162	143	305	53.1
10–19 February	108	106	214	50.5
20 February–1 March	129	130	259	49.8
2–11 March	75	75	150	50.0
12–21 March	114	119	233	48.9
22–31 March	73	67	140	52.1
1–10 April	112	102	214	52.3
11–20 April	113	94	207	54.6
21–30 April	152	143	295	51.5
1–10 May	139	143	282	49.3
11–20 May	67	56	123	54.5
21–30 May	124	106	230	53.9
31 May–9 June	27	24	51	44.3
10–19 June	62	59	121	51.2
20–29 June	50	65	115	43.5
30 June–9 July	19	19	38	50.0
10–19 July	9	8	17	52.9
Total	1,568	1,513	3,081	50.89

[1] 1952: 319 fetuses from American waters and 606 from Asian. From American waters: 1955, 97; 1958, 982; 1959, 1,077. The table has been compiled from data on original field-record cards.

TABLE 2.—POSTNATAL SEX RATIOS OF FUR SEALS, AUGUST–SEPTEMBER[1]

Year	Number of Pups			Percent Males
	Male	Female	Both	
1950	505	495	1,000	50.5
1957	653	547	1,200	54.4
1958	127	121	248	51.2
1959	626	574	1,200	52.2
Total	1,911	1,737	3,648	52.38

[1] Examined on Pribilof Islands.

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USE OF DYES TO MARK RUMINANT FECES[1]

Fred Kindel

Idaho Department of Fish and Game, Salmon, Idaho

Dyes and other staining materials have been used as external marks in attempts to trace animal movements (Clover, 1954; Taber, *et al.*, 1956). New (1958) stained the scats of small mammals to trace their movements. This paper reports experiments in marking the feces of ruminants with dyes to trace the movements of wild ruminants.

EXPERIMENTS WITH SHEEP

In experiments conducted at the University of Idaho in 1956, certain water-soluble dyes fed to domestic sheep passed through the ruminant digestive system and imparted a stain to the fecal pellets. A total of 23 dyes and dye-materials were tested. Four dyes imparted a good stain to the feces: methylene blue produced a blue-green stain; crystal (gentian) violet produced a violet stain; basic fuchsin produced a red stain; and aniline blue (water soluble) produced a deep blue stain. Five other dyes also stained the feces but to a lesser degree. Among these, sulfogene indigo blue G (concentrated) produced a blue stain; and neutral red, safranin O, rose bengal, and alizarin red S all produced reddish stains. Other dyes and dye-materials tested which produced negative results were: eosin blue, ahcoquinone violet base (oil soluble), methyl orange, malachite green, janus green B, barium sulphate, ferric oxide, chromium trioxide, picric acid, FD&C[2] Red No. 2, FD&C Yellow No. 4, FD&C Yellow No. 5, and D&C[2] Red No. 17.

The dyes, in powder form, were mixed with dry, ground feed and salt, and fed to penned sheep. Methylene blue was fed in 1-, 2-, and 3-gram doses, which produced similar staining results. All other dyes were fed in single doses of approximately 10 grams.

The effective dyes appeared in the feces of the sheep approximately 24 hours after ingestion, and continued to appear for 2 to 4 days afterwards.

Observations of the effects of weathering on the stained sheep pellets showed that the color remained in the fecal pellets as long as the pellets themselves resisted the effects of weathering. However, when the outer surface of the pellets oxidized to the normal brown or black, it was necessary to break open or crush the pellets to reveal the color of the inner fecal material.

FIELD TRIALS WITH ELK

It was assumed that dyes marking feces of sheep would also pass through the digestive system of other ruminant animals such as elk. To substantiate this, a limited investigation was made with elk in the Selway area of Idaho in connection with studies of elk movements in relation to salting (Kindel, 1958). Three dyes were obtained for field trials with elk. Methylene blue, crystal violet, and basic fuchsin were obtained in quantity (5 to 10 pounds) from the National Aniline Division of the Allied Chemical and Dye Corporation, San Francisco. Granular salt was mixed with the powdered dyes and distributed in small wooden boxes for elk.

Several pellet groups of elk were found which were vividly marked with the dyes, demonstrating the usefulness of dyes to trace the local movements of wild ruminants. Another use for dye-marked ruminant feces may be in separating the feces of individual animals in the same pasture in connection with digestibility trials such as those conducted by Corbin and Forbes (1951).

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[1] Contribution from the Idaho Department of Fish and Game Pittman-Robertson Project W–85–R–8 and the Idaho Cooperative Wildlife Research Unit.

[2] Refers to the listing of pure food colors by the Federal Food, Drug and Cosmetic Act of 1938 (U.S. Food and Drug Administration, 1940).

RELATIONSHIP OF PHEASANT NESTS TO HAYFIELD EDGES[1]

Maynard M. Nelson, Robert A. Chesness, and Stanley W. Harris[2]

Minnesota Division of Game and Fish, St. Paul, Minnesota

The purpose of this paper is to provide a better understanding of the location of pheasant nests in relation to field edges. While numerous studies have been made of the nesting behavior of the pheasant (*Phasianus colchicus*), conclusions of various researchers regarding the presence or absence of an "edge effect" have frequently disagreed.

Hamerstrom (1936) and Wight (1950) reported that pheasants tended to nest near the edges of the fields while Leopold (1937) and Leedy (1938) found no such evidence. Leopold (1937) suggested that crowding of nests might force the birds to accept non-peripheral sites, and Randall (1939) reported a trend away from peripheral locations as populations increased.

Many authors have presented figures that show a high percentage of the total nests within 50 to 100 feet of an edge and have interpreted this as evidence of an "edge effect." However, in most cases there are no references to the *proportion of the total acreage* within the same 50- to 100-foot zone. Hamerstrom (1936) found that 54 percent of the nests in alfalfa occurred within 50 feet of the field edge and used this as evidence of an "edge effect." He made no statement, however, concerning what percentage of the total acreage was within 50 feet of the edge. Wight (1950) found 42 percent of the nests within 50 feet of the edge but gave no information on acreages. He also interpreted his data to be indicative of an "edge effect." Baskett (1947), who reported no evidence of an "edge effect" in field nests, found from 29 to 40 percent of the nests within 50 feet of the edge, but made no statement concerning acreage. Klonglan (1955) divided his fields into inside and outside halves and into thirds and concluded that there was no "edge effect" in nest placement.

The authors obtained information on the placement of 508 pheasant nests in 644 acres of hay in Martin County, Minnesota during 1957 and 1958. Over 85 percent of the acreage represented alfalfa with smaller amounts of red clover and grass types. In the 2 years, 67 fields were completely checked by systematic search following removal of the first cutting of hay. Fields were generally rectangular in outline although a small number were of odd shapes. Fields averaged 9.4 acres and ranged from 1.7 to 36.6 acres. The location of all nests in relation to field edge was determined by measuring with a tape or by pacing. Fields were then divided into zones with reference to distance from an edge and the percentage of the total nests for each zone was compared to the percentage of the total acreage which was found within the same zone (Table 1).

TABLE 1.—PLACEMENT OF PHEASANT NESTS IN RELATION TO FIELD EDGE AND ACREAGE, 1957–58

Distance from Edge in Feet	Number of Acres	Number of Nests	Percent of Acreage	Percent of Nests
0–50	200.3	168	31.1	33.1
51–100	158.2	117	24.6	23.0
0–100	358.5	285	55.7	56.1
101–200	198.1	145	30.8	28.5
201–300	70.9	66	11.0	13.0
301–400	13.4	10	2.1	2.0
401–600	3.0	2	0.5	0.4
Totals	643.9	508	100.1	100.0

A total of 56.1 percent of all nests was located within 100 feet of the field edges, while only 28.5 percent was located in the next 100 feet. At first glance, this may seem like evidence of an "edge effect," but 55.7 *percent of the total acreage* was also within 100 feet of the field edges and 30.8 percent of the acreage was in the next 100 feet. In fact, when the percentage of nests found in any given zone is compared with the percentage of the acreage in the same zone, it is apparent that there was no tendency for the hens to nest in any one zone in greater proportion on the basis of acreage than in any other zone. Data considered for either year alone led to this same conclusion—nests are placed at random in the fields without reference to an edge. There would be no greater management value, therefore, in delaying mowing on the outside edge of the fields than delaying it on a similar acreage located in any other portion of the fields.

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[2] Presently an instructor at Humboldt State College, Arcata, California.

A COLORED LEG STRIP FOR MARKING BIRDS

Dan L. Campbell

Patuxent Wildlife Research Center, Bureau of Sport Fisheries and Wildlife, Laurel, Maryland

Plasticized polyvinyl chloride extruded strips have been found useful for color marking birds. Craighead and Stockstad (J. Wildl. Mgmt., 20:331–332. 1956) described this material and a procedure for making neck bands. Recently their design was modified by Downing and Marshall (J. Wildl. Mgmt., 23:223–224. 1959).

A new method for attaching such strips was devised for use on redwinged blackbirds (*Agelaius phoeniceus*). A ¼-inch slot was punched longitudinally near the center of a strip ¼ inch wide, 1¾ inches long, and 0.062 inch thick. Through this slot a U. S. Fish and Wildlife Service numbered aluminum size 2 band was inserted and closed around the tarsus of the bird (Fig. 1).

The efficiency of this method of color marking was tested on both caged and free-flying redwings and compared with neck banding. Confined birds with neck bands thrashed about the cage and stepped on their own neck bands. Other birds in the cages pecked at the hanging strips. Because of disturbance caused by neck bands, I removed them after ½ hour. Birds with leg strips pecked at the strips, as they commonly do at metal leg bands when first attached. Leg strips caused no other discomfort or interference with normal activities. No apparent injury was caused by the leg strips on captive birds held for 6 months.

Two male redwinged blackbirds marked with leg strips were observed on their territories over a 3-month period. They always exhibited behavior typical of unmarked birds. Six other males were marked, but only three of them were sighted after being marked. These six males probably were not resident birds. One female redwing seen on its nest was not impeded by a leg strip. A territorial male redwing with neck band and colored celluloid leg bands (not strips) behaved normally but lost the neck band in a month's time. At the end of the month, its neck feathers showed extreme wear. The colored leg bands were lost within a year.

No loss of leg strips was noted on the birds studied. Because of the pliability of the strips, the birds are not likely to become entangled. The plastic retains its original shape and color and does not tear or break. It is usually visible when the bird is either standing or flying. Red, orange, or yellow strips ¼ inch wide usually can be seen readily at 50 yards without binoculars.

The plasticized material is available in other colors. If different combinations are desired, a strip can be put on each leg. An unnumbered band may be used for attaching the second strip.

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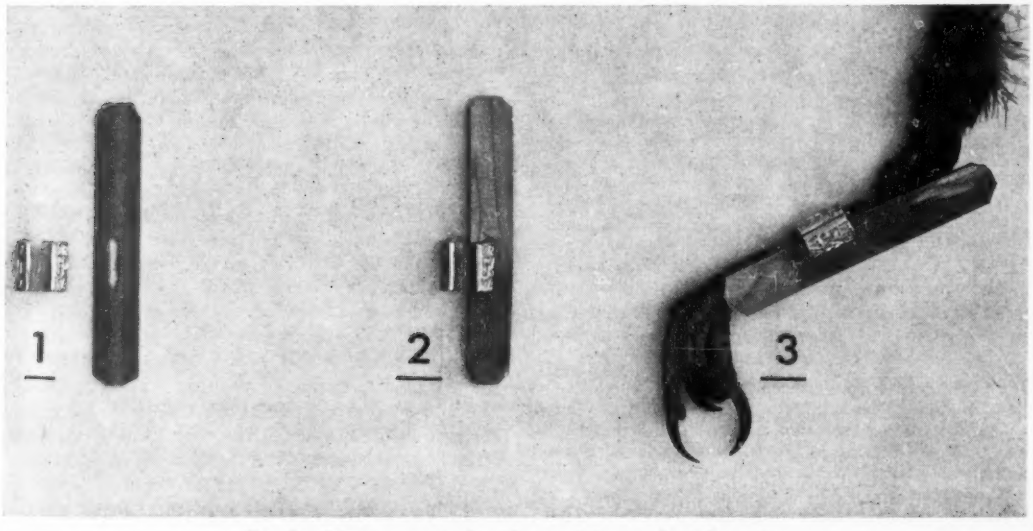

FIG. 1. Three-step procedure for attaching a colored leg strip.

A THOUSAND MILES OF FOX TRAILS IN MICHIGAN'S RUFFED GROUSE RANGE[1]

Raymond D. Schofield

Michigan Department of Conservation, Lansing 26, Michigan

The tracking technique has been used by several investigators for the study of the larger predatory animals. Stebler (1939) says: "Stated simply, the method consists of following the trails left by these mammals and interpreting from the clues they may leave, their activities and behavior." Murie (1936) notes: "It is practically equivalent to observing an animal for a long period of time under natural conditions."

The method has been used rather extensively by biologists of the Michigan Department of Conservation to study the winter habits of wolves (*Canis lupus*), coyotes (*Canis latrans*), bobcats (*Lynx rufus*), and red foxes (*Vulpes fulva*). Our weather usually solves the most serious limitation of the technique by providing suitable tracking snow from late November to early April.

Arnold (1956) trailed foxes to determine their winter food habits in the agricultural areas of southern Michigan, the principal pheasant range of the state. His study involved following fox trails a thousand miles. We conducted the present study primarily to determine the effects of red foxes on ruffed grouse (*Bonasa umbellus*) during the winter in the northern "wild land" portion of the state. Field work began in the fall of 1955 and continued for three winters.

The areas selected for study were in the northern half of the Lower Peninsula. A large share of the work was done on the Gladwin Field Trial Area (8 square miles) and the Rifle River Area (7 square miles). Both are state-owned and were used by Palmer (1956) for his survey of grouse on hunted and unhunted areas. His work continued during this study, providing needed population data on ruffed grouse.

Cover types at Gladwin and Rifle River are typical of most of the Lower Peninsula's ruffed grouse range (Schofield, 1960).

METHODS

Our procedure in tracking foxes varied little from those of Arnold (1956). We followed trails in the snow and recorded fox habits, kills, food eaten, and cover type preferences. At the completion of each day afield these observations were entered on standard tracking record forms. We measured distances by counting paces with pocket "tally-whackers" (Veedor counters).

Early in the study it became apparent that white-tailed deer (*Odocoileus virginianus*), shot and left in the woods during the November hunting season, were the primary winter food of foxes on the study areas. An attempt was made to measure this waste of deer and to determine the amount of venison available to foxes (Schofield, 1960).

RESULTS

Food Habits

Deer shot and wasted by hunters during the November deer season made up the bulk of the winter food of foxes on the areas studied. Mice (*Microtus* and *Peromyscus*) and shrews (mostly *Blarina brevicauda*), porcupines (*Erethizon dorsatum*), and cottontail rabbits (*Sylvilagus floridanus*) were prominent food items. Table 1 presents a summary of the fresh kills and other items located along 1,109 miles of fox trails in the ruffed grouse range during three winters (December 1955 to April 1958). On the average, foxes visited one deer carcass for each 5.5 miles of trail. Early in the winter, viscera from field-dressed deer were important food. Porcupines noted frequently along the trail were probably shot by hunters.

Evidence of fox predation on game species was negligible. Five cottontails, two bobwhites, and one snowshoe hare were the only game *killed* by the foxes we followed. None of the 19 dead grouse found along the trails were killed by the foxes while they were making the more than a thousand miles of trails we followed. We were sure from the available evidence that hawks or owls killed at least four of the birds. Of course, some of the others might have been killed earlier by foxes.

Foxes spent a lot of time hunting mice and shrews, but we had difficulty in determining their success. Often just a drop of blood on the snow would be the only evidence indicating a kill. In Table 1, these small mammals are lumped together because of the impossibility of distinguishing whether a mouse or a shrew had been taken. We collected fox scats along the trails to obtain further information on the importance of these animals in the winter diet. By analyzing this material, it was possible to identify remains of mice and shrews much more easily than by visual inspection of the fox trail. Results of the scat ana-

[1] A contribution from Pittman-Robertson Research Project W-69-R, Game Division, Michigan Department of Conservation. I wish to thank all of the personnel of the Department's Game Division who assisted with the study. Student aides, employed as fox trailers, have my sincere thanks. S. C. Whitlock and R. A. MacMullan deserve special mention because of their helpful suggestions. C. T. Black edited the manuscript.

TABLE 1.—FRESH KILLS AND OTHER ITEMS LOCATED ALONG 1,109 MILES OF FOX TRAILS

Item	Fresh Kills	Fox Visits
MAMMALS		
White-tailed deer (*Odocoileus virginianus*)		203
Mice and shrews[1]	123	57
Porcupine (*Erethizon dorsatum*)		43
Cottontail rabbit (*Sylvilagus floridanus*)	5	25
Mole (*Scalopus* sp. and *Condylura* sp.)	5	8
Raccoon (*Procyon lotor*)		6
Skunk (*Mephitis mephitis*)		6
Snowshoe hare (*Lepus americanus*)	1	5
Black squirrel (*Sciurus carolinensis*)		5
Muskrat (*Ondatra zibethica*)		4
Fox squirrel (*Sciurus niger*)		3
Red squirrel (*Tamiasciurus hudsonicus*)		2
Weasel (*Mustela* sp.)		2
Mink (*Mustela vison*)		2
Red fox (*Vulpes fulva*)		2
Cow (*Bos taurus*)		1
Woodchuck (*Marmota monax*)		1
Unknown mammal		9
BIRDS		
Ruffed grouse (*Bonasa umbellus*)		19
Blue jay (*Cyanocitta cristata*)		3
Bob-white quail (*Colinus virginianus*)	2	1
Hawk (*Buteo* sp.)		2
Mourning dove (*Zenaidura macroura*)		1
Domestic chicken (*Gallus gallus*)		1
Canada goose (*Branta canadensis*)		1
Woodcock (*Philohela minor*)		1
Unknown bird		1
MISCELLANEOUS		
Deer entrails		121
Fish (Pisces)		2
Frog (*Rana* sp.)		2
Ruffed grouse eggs		1
Garter snake (*Thamnophis sirtalis*)		1
Painted turtle (*Chrysemys cinerea*)		1

[1] Most of the shrews were *Blarina brevicauda* and most of the mice belonged to the genera *Microtus* and *Peromyscus*.

lysis revealed deer, mice, and rabbits as the most important winter foods (Table 2).

Food Availability

Food habits studies are not complete without some consideration of the availability of the food. During this study, ruffed grouse and snowshoe hares were near the bottom of their 10-year cycles. Yet, fresh grouse sign occurred along 67 percent of the fox trails followed. Biologists tracking foxes flushed 223 ruffed grouse, 1 bird per 5 miles walked. Snowshoe hare tracks occurred along 55 percent of the fox trails and cottontail sign along 39 percent.

Biologists from the Houghton Lake Wildlife Experiment Station conducted intensive ruffed grouse censuses on the Rifle River and Gladwin areas. They computed early fall, December, and spring populations for a square-mile unit on each area. For the purposes of this study, I averaged their December and spring population figures to get an estimate of the winter density of birds on each area. These calculations indicated that there was a winter population of two to four birds per 100 acres on the study units during the three winters we tracked foxes. Earlier censuses by Palmer (1956) indicated that grouse numbers declined considerably from the "high" years of the cycle—1950, 1951, and 1952. During these years his censuses showed winter grouse populations of 5 to 10 birds per 100 acres for the study units.

Biologists assigned to the Rifle River and Gladwin areas during the deer seasons of 1956 and 1957 located and marked 41 illegally shot deer. Fox trackers later located 27 of these marked deer and 34 additional unmarked carcasses. Lincoln-index calculations indicate an annual waste of slightly over four deer per square mile on the two study areas.

Antlerless deer in this part of Michigan probably averaged about 100 pounds live weight, providing foxes with over 400 pounds of potential food per section. Foxes in this part of the state have practically no competition from other scavengers during the winter. Consequently, this amount of venison will support a high fox population during this critical period.

Daily Range of Foxes Trailed

Scott (1943) estimated from his observations "that an arc drawn on a one-mile radius would or-

TABLE 2.—FREQUENCY OF FOOD ITEMS IN 138 RED FOX SCATS FROM WINTER PERIODS, 1955–57

Food Item	Percent Occurrence
MAMMALS	
White-tailed deer (*Odocoileus virginianus*)	68.1
Cottontail (*Sylvilagus floridanus*)	23.2
Meadow vole (*Microtus pennsylvanicus*)	21.7
Deer mouse (*Peromyscus* sp.)	18.8
Porcupine (*Erethizon dorsatum*)	8.0
Shrew (*Blarina brevicauda*)	7.2
Muskrat (*Ondatra zibethica*)	6.5
Skunk (*Mephitis mephitis*)	3.6
Snowshoe hare (*Lepus americanus*)	2.9
Flying squirrel (*Glaucomys* sp.)	2.2
Prairie mole (*Scalopus aquaticus*)	2.2
Cow (*Bos taurus*)	2.2
Black squirrel (*Sciurus carolinensis*)	1.4
Red-backed vole (*Clethrionomys gapperi*)	0.7
Pine vole (*Pitymys pinetorum*)	0.7
Weasel (*Mustela* sp.)	0.7
Striped ground squirrel (*Citellus tridecemlineatus*)	0.7
Unknown mammals	8.0
BIRDS	
Ruffed grouse (*Bonasa umbellus*)	3.6
Unknown birds	8.7
MISCELLANEOUS	
Vegetation	31.9
Traces of fox hair	2.9
Unknown material	5.8

TABLE 3.—COMPARISON OF COVER TYPE PREFERENCES OF RED FOXES IN WINTER WITH COVER TYPES AVAILABLE

Type	Gladwin Field Trial Area		Rifle River Area	
	Percent of Fox Trails in Type	Percent of Area in Type	Percent of Fox Trails in Type	Percent of Area in Type
Aspen	40.4	35.4	36.6	41.5
Oak	39.1	40.9	9.9	2.0
White birch	1.7	7.2	1.0	tr.
Open	8.0	6.4	12.4	13.6
Conifer swamp	3.7	6.3	8.7	6.9
Marsh (old beaver floodings)	0.4	1.8	4.4	5.6
Lowland brush	3.8	0.4	15.8	9.0
Lakes and rivers	2.0	0.9	8.8	8.0
Swamp hardwoods	0.9	0.7	2.2	13.2
Pine	tr.	tr.	0.2	0.2

dinarily circumscribe the movements of the resident individual, pair, or family" of foxes in Iowa. As it was not possible to follow day-to-day movements of individual foxes in our study, we attempted to determine daily range from the trailing data. A total of 84 foxes were jumped from their daytime beds. The average distance traveled from the point of interception of the fox trail to its bed was 3.64 miles. The straight-line distance from the point of interception to the fox bed averaged almost 1 mile (.94).

Arnold and Schofield (1956) calculated the nightly hunting range of the red fox in the southern agricultural area of the state to be 1.4 square miles. This was based on the assumption that the observer, on the average, intercepts a fox trail at the midpoint and the average distance from the point of interception to where the fox was jumped should approximate the radius of a circle equal in size to the area over which the fox hunts in one hunting period.

Whether this assumption is true is not known, but it does offer a method for comparing daily movements of foxes between the two areas. As the average straight-line distance from the point of interception of the fox trail to the fox bed was calculated as .94 mile in the north, the nightly hunting area of foxes there would be 2.8 square miles, twice as large as the area hunted nightly by southern Michigan foxes.

Cover Type Preference of Foxes Trailed

Scott (1943) attempted to determine the fox's relationship to different cover types by counting paces taken along trails in each type. Because of the difficulty in following an individual fox, the method did not prove productive in Iowa. We had fairly good success staying on individual fox trails and we carefully recorded distances traveled in each cover type (Table 3). Foxes that were followed seemed to have shown a slight preference for lowland brush on both the Gladwin and Rifle River areas and to have hunted in the oak type a little more than expected at Rifle River. Conversely, white birch, marsh, and conifer swamp types were avoided at Gladwin as was the swamp hardwood type at Rifle River. It is recognized that some bias was introduced by the trailing habits of fox trackers. For example, there was a distinct reluctance for biologists to follow fox trails across the ice on beaver floodings.

SUMMARY

Biologists trailed red foxes 1,109 miles in Michigan's ruffed grouse range. Predation on game was negligible. The primary winter food of foxes was illegally killed deer, left from the fall hunting season, amounting to slightly over 4 deer per square mile and providing foxes with about 400 pounds of food per section. Foxes still hunted mice extensively.

Foxes in the northern half of the Lower Peninsula hunted about 2.8 square miles nightly and apparently ranged farther than southern Michigan foxes. The northern foxes showed a slight tendency to prefer lowland brush areas.

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COLOR MARKER FOR BIG GAME

John J. Craighead and Dwight S. Stockstad

U. S. Fish and Wildlife Service, Missoula; and Montana State Fish and Game Department, Kalispell, Montana

In population studies it is necessary to recognize and observe in the field individuals and age classes over a period of several years. When this can be accomplished with a high degree of certainty, data can be obtained on breeding age, breeding behavior, and daily and seasonal movements of individuals. Similar data as well as information on sex, age structure, mortality, and behavior can be obtained for the population unit. Under favorable conditions, accurate population counts can be derived from ratios of marked to unmarked animals observed.

Many methods of marking individuals and age classes in big game populations have been tried. However, there is still need to develop, through field testing, a permanent visible marker applicable to young and adults of various big game species. This paper reports some progress along this line.

Mutilation has been recognized as a permanent marker for field identification. A clipped or notched ear, a docked tail, a dismembered toe, fur clipping, and branding have all been used; but visibility has generally been poor unless mutilation was drastic. Branding has possibilities still not fully explored; but to be visible, the brand must be large, and younger animals may be maimed. Aldous and Craighead (1958) successfully marked bighorn sheep (*Ovis canadensis nelsoni*) by branding the horns.

Various visible markers have been used with some degree of success. A brass neck collar that would adjust with growth was used on foxes by Sheldon (1949). Ealey and Dunnett (1956) used plastic collars on nocturnal mammals and Progulske (1957) developed a leather collar for marking white-tailed deer (*Odocoileus virginianus*). Jordan (1958) successfully belled mule deer (*Odocoileus hemionus*) in California, using leather strap collars. Retrapping showed that 4 out of 29 straps broke within a 15-month period. Because of the danger of constriction during future growth, Jordan concluded that it was not advisable to use a collar on fawns, and that bucks should not be belled with a permanent neck strap or chain before the age when growth is nearly complete. Progulske (1957) had earlier reached similar conclusions for white-tailed deer. Jordan (1958) suggested the use of a non-permanent material such as ribbon or straps or chains with a weak link. Such devices are valuable for certain purposes but insure a non-permanent rather than a permanent marker.

The development of a permanent color marker involves the testing of marker material for durability, color retention, and methods of attachment. Although this paper is confined to describing a color marker for big game, the conclusions reached with regard to color retention and visibility of marking material were first derived from work with birds and then found to apply to color-marking of large mammals. Plasticized polyvinyl chloride tape was

FIG. 1. Attachment of color marker and numbered ear tag. The jesse knot is loosely tied to show method but should be cinched tight to complete the tie.

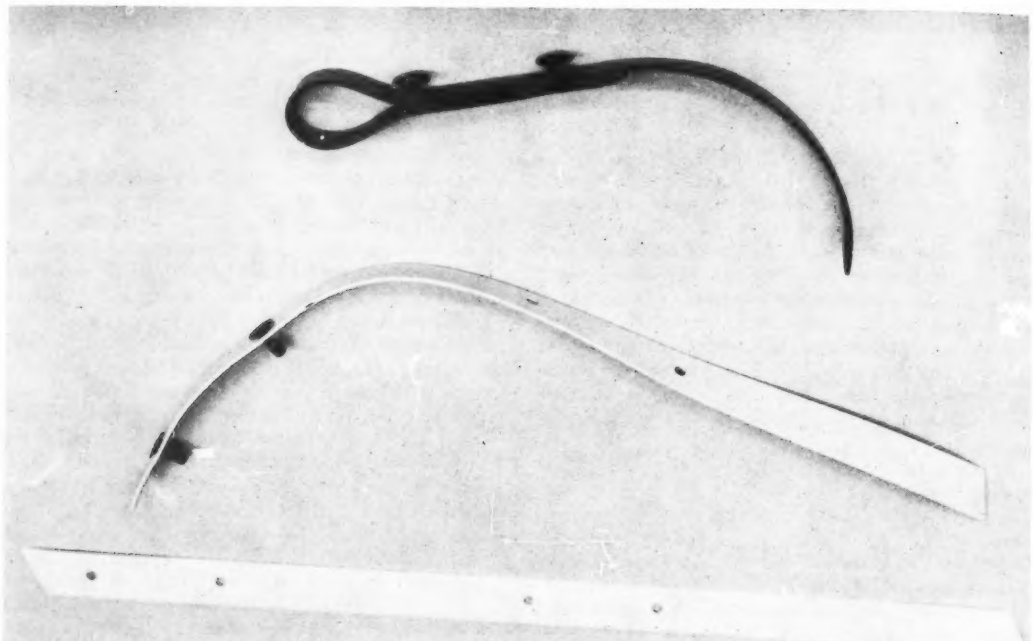

FIG. 2. Method of securing plastic marker with rivets. Numerous color combinations can be made by splicing different color tapes between the loop to form a tail. Tail and loop are then of different colors.

selected for testing and first used on Canada geese (*Branta canadensis*) by Craighead and Stockstad (1956).

Over a 5-year period, 538 Canada geese, 3,900 game farm pheasants (*Phasianus colchicus*), and 1,225 American magpies (*Pica pica hudsonia*) were color marked with this durable tape.

Hundreds of observations of these marked birds showed that polyvinyl chloride tape could be readily observed in the field. It did not become unduly brittle at low temperatures and retained its color for a period of several years under field conditions. The ½-inch tape, 0.062 inch thick, proved highly durable. Some markers on wild Canada geese have held color and remained intact for 5 years; magpies have retained markers for 4 years, and released game farm pheasants 2 years. In the latter case this represented the longevity of the released pheasants.

The more visible colors under a wide range of field conditions were yellow, red, white, and blue. Orange was highly visible but could be confused with red when both colors were used. Violet was least visible. Green and pink were readily recognized, but under poor light conditions could be confused with blue and white respectively when all four of these colors were used. Under favorable light conditions and with sufficient time for observation all colors could be identified with certainty. By splicing with rivets, 64 combinations are possible. Judgment must be used in omitting the less visible colors and confusing combinations. The colors and combinations selected for use will vary with the species marked and the difficulty of observation.

In developing a color marker for big game we were particularly concerned with testing methods of attachment and confirming work already done on color retention and durability of materials. The metal ear tag and metal disk combination has been used by many workers. This marker was used on 15 penned elk (*Cervus canadensis*) at the National Bison Range, Moiese, Montana. Visibility was poor unless an excessively large disk was used. The constant movement of the disk hindered observation and caused the ear tags to pull out. Irritation and inflammation occurred; in some instances a portion of the ear sloughed off. The plastic disks were brittle and broke during cold weather. Some metal disks tended to fade and lose color after a short period of time. These latter drawbacks can be largely remedied, but the attachment of visible disk markers to ear tags simply invites loss of the ear tags and cannot be considered as a permanent marker.

Our experience in color-marking of birds had shown the merits of plasticized polyvinyl chloride tape. We first tested this in 1954 on big game by

attaching the tape to metal ear tags on penned mule deer and 23 elk at the National Bison Range. The visibility of this marker was excellent, but retention was unsatisfactory. In less than 1 year some ear tags pulled out from the weight and movement of the plastic streamer; irritation of the tissue occurred on nearly all animals tested.

Further experiments with the plastic tape were conducted on elk calves released on the National Bison Range. Plastic tape was threaded through a slit made in one ear and fastened with the jesse knot (Fig. 1). The technique of slitting the ear was simultaneously and independently conceived by us and Aldous and Craighead (1958). This method of attachment has been reported by them, but without detailed description or evaluation of the method.

METHOD

The procedure is simple and rapid. The lower edge of the ear is sponged with alcohol. A ¾-inch longitudinal slit is made in the cartilaginous basal portion of the ear approximately 1 inch from the edge. This should be done with a razor-sharp scalpel or pocket knife. There appears to be little or no pain and bleeding is slight. The plastic tape (8 to 10 inches long) is dipped in alcohol, threaded through the incision and tied as described by Craighead and Stockstad (1956). Punch-hole centers (3½–4 inches apart) form a loop that will not bind and allows amply for ear growth. The ear should be wiped with alcohol or other disinfectant before the animal is released. Quick-set rivets can be used in place of the jesse knot (Fig. 2). Experiments currently under way on bighorn sheep (*Ovis canadensis canadensis*) and grizzly bear (*Ursus horribilis*) indicate rivets may be more durable than the knot but slightly more time consuming to install.

RESULTS

Six elk calves, ear-tagged and color-marked with yellow, green, orange, white, violet, and red tape were released on the National Bison Range in December 1956 and collected a year later. Inspection of the ears and markers revealed no loss of the colored plastic markers. Neither breakage nor wear occurred and none of the colors, with the exception of violet, showed any apparent fading.

In each instance, the incision had healed, developing little or no scar tissue. A slit, only slightly larger than the tape, was present with no evidence of irritation or sloughing.

In 1957, 10 more elk calves were marked and released with the objective of collecting them over a period of years. The first two animals collected 10 months after marking showed no irritation or infection where the ear had been slit. The markers were in excellent condition. A third animal was shot after 20 months. The ear had healed with no scar tissue present; the marker was intact but a slight crack had developed at the corner of one of the punch holes. A fourth elk collected 21 months after marking still had the plastic marker in the ears but the tail of the marker had broken. This elk could be recognized as a marked animal only with difficulty. The ear was in excellent condition. Color retention was good in all cases.

During the winter of 1959, biologists of the Montana State Fish and Game Department color-marked a number of wild elk in the manner described. Approximately a year later, four of these animals were retrapped and examined. Two animals had lost their ear markers and two had retained them. No information was obtained on the condition of the ears.

It is believed that the method of color-marking described is applicable to a wide range of large and medium-sized mammals and may have advantages over other methods currently in use. However, it is evident that a more durable but flexible tape with similar color retention would greatly prolong usefulness and could conceivably last the lifetime of an animal, thus classing it as a permanent marker. The authors believe such a tape can be developed. One possibility is to imbed a thin nylon fabric in the plasticized polyvinyl chloride tape to prevent breakage, especially at low temperatures. Since flexibility and lightness are essential, increasing the thickness of the tape does not appear to be a solution. Perhaps there are other synthetics on the market or currently being developed that will qualify. The value of a permanent or near-permanent color marker for big game is such that special effort should be made to obtain or develop a suitable material. Our experiments on marking elk would indicate that threading a tape through a slit in the ear produces a marker limited in longevity only by the durability of the tape. Preliminary tests on bighorn sheep lambs and grizzly bears show that this marking method has promise for these species.

SUMMARY

Color-marking of big game by ear-slitting and inserting colored plasticized polyvinyl chloride tape is described and the results evaluated. The advantages of the method described are that very young as well as adult animals can be safely marked. There have been no adverse effects on the animals tested. The tape can be easily and rapidly attached. Color retention is good and at least eight different colors can be used, some being more visible than others. Threading a tape through a slit in the ear produces a marker limited in longevity only by the durability of the tape.

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APPARENT ABSENCE OF RABIES IN ILLINOIS SHREWS

B. J. Verts and Thomas R. B. Barr

Illinois Natural History Survey; and College of Veterinary Medicine, University of Illinois, Urbana, Illinois

A study of sylvan rabies was begun in Illinois in 1957 (National Institutes of Health Project E-1349) to determine the reservoir species in nature, and the relationship between the incidence of rabies in these species and their distribution patterns and populations. Although to our knowledge rabies has not been reported in shrews, two insectivores, the Eurasian mole (*Talpa europaea* Linnaeus) (Nikolitch, 1957) and the hedgehog (*Erinaceus europaeus* Linnaeus) (Greval and Nicholas, 1940) have been reported as possible natural hosts. This fact influenced our decision to examine shrews in northwestern Illinois. Additional considerations were the wide distribution of shrews in the United States, and the aggressive nature, voracity, and predatory habits of many species.

Two hundred and sixty-six shrews, taken in snap traps between December 2, 1957, and January 16, 1959, were tested. All of these were captured within 25 miles of a location where a case of rabies had been confirmed within 12 months before, or after, their capture. Twenty specimens were collected from within 1¼ miles and 10 from within ½ mile of such a location.

Samples of brain tissue, or of both brain and salivary gland tissues, were removed in the laboratory. These were kept in storage in separate tubes, in a solution of 50 percent glycerine and 50 percent twice-normal saline, at minus 20° C., until all tests for rabies virus in them had been completed.

The laboratory technique used for the diagnosis of rabies was essentially the mouse inoculation test described by Koprowski (1954). Brain and salivary gland tissues were tested in pools of three to five (usually four) like tissues. A 10 percent suspension was prepared from each pool. The diluent consisted of a physiological saline solution containing 10 to 20 percent inactivated, nonimmune, bovine serum and 1,000 units of sodium citrate buffered crystalline penicillin G potassium and 3.0 mg. of crystalline dihydrostreptomycin per ml. Tissue suspensions were incubated at 37° C. for 30 to 45 minutes before inoculation. Five 3- to 4-week-old, Swiss white mice were used to test each brain and salivary gland pool. Each mouse was inoculated intracerebrally with 0.03 ml. of the supernatant fluid from a tissu ension.

TABLE 1.—SPECIES OF SHREWS AND NUMBERS OF TISSUES FROM EACH THAT WERE EXAMINED FOR RABIES IN ILLINOIS, DECEMBER 2, 1957–JANUARY 16, 1959

Species	Number of Brains Examined	Number of Salivary Glands Examined
Blarina brevicauda	226	116
Sorex cinereus	34	7
Cryptotis parva	6	0
Totals	266	123

Mice which succumbed within 48 hours after inoculation were considered to have died from causes other than rabies virus (trauma, bacterial contamination, other viruses). The observation period for the inoculated mice was 28 days after inoculation. Crush smears prepared from brain material of mice dying within this period were stained by a modification of Williams' method (Coffin, 1953) and examined under the microscope for the presence of Negri bodies. Retests were performed by inoculating five other mice intracerebrally with a suspension of brain material from the dead mouse (or mice).

Table 1 indicates the species and the numbers of tissues from each that were examined. Rabies virus was not demonstrated in any of the tissues.

Since none of the shrews was infected, it is believed that the possibility of their being important reservoirs of rabies in this area is remote.

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REARING AND BREEDING WHITE-TAILED FAWNS IN CAPTIVITY[1]

Dean A. Murphy

Missouri Conservation Commission, Columbia, Missouri

Providing a diet adequate for growth and reproduction has been a major problem in rearing fawns taken from the wild (Silver and Colovos, 1957; French, *et al.*, 1955). We encountered this problem in establishing a captive deer herd in Missouri, and provided adequate nutrition for growth and reproduction by feeding an enriched formula which simulated deer milk.

The author wishes to acknowledge the technical assistance of the following faculty members of the University of Missouri: George Garner, William O. Regan, and Charles Turner. The deer milk sample was analyzed by the Chemical Laboratory, Agricultural Experiment Station, University of Missouri, under direction of Charles W. Gehrke.

Procedure

During the summer of 1958, nine fawns taken from the wild were brought to the Green Wildlife Experiment Station near Columbia, Missouri. The fawns were estimated to be from 1 to 5 weeks of age when received.

The fawns were fed a variety of rations, including skimmed milk, powdered milk, condensed milk, fresh whole milk, and a commercial milk substitute for calves. They failed to gain weight and constipation or diarrhea frequently occurred. It was evident that a diet more nearly simulating deer milk was needed.

A preliminary survey of the literature revealed no published record of the composition of milk from white-tailed deer (*Odocoileus virginianus*). (The analyses reported by Ruff (1938) were located after this project was completed). Composition of milk from mule deer (*Odocoileus hemionus*) was reported by Browman and Sears (1955). Composition of milk from black-tailed deer (*Odocoileus hemionus columbianus*) was reported by Hagen (1951) and Kitts, *et al.* (1956). The latter authors, who reported the most complete analysis, suggested a formula to enrich cow's milk for feeding fawns. Their formula was fed to our fawns but severe scouring occurred. Dr. Garner suggested that the scouring occurred because of improper emulsification of the vegetable oil in the formula. He also prepared a formula which would enrich condensed milk to approximate the composition of black-tailed deer milk. The milk substitute was prepared by adding the following ingredients for each quart of condensed milk:

Protein	
Casein	110 gm.
Fat	
Mazola oil (corn oil)	120 gm.
Vitamins	
Vitamin A	3500 I.U.
Vitamin D	350 I.U.
Choline	480 mg.
Inositol	40 mg.
Asorbic acid	30 mg.
Vitamin B_{12} suspension	10 mg.
Ca pantothenate	10 mg.
Niacin	4 mg.
Riboflavin	2 mg.
Pyridoxine	2 mg.
Thiamin HCl	1 mg.
Folic acid	.01 mg.
Biotin	.01 mg.
Major minerals	
Ca H PO_4	1.15 gm.
Mg O	.50 gm.
Trace elements–dissolved in 5 cc. of water	
Co Cl_2	.5 mg.
Fe Cl_3	15 mg.
Cu O_2	1 mg.
Emulsifying agent	
Soybean lecithin	9 gm.

The casein, major minerals, and vitamins (except A and D) were mixed together in a feed mixer and stored in a closed container. The Mazola (corn) oil, vitamin A and D oils, and lecithin were mixed by blending at low speed and also stored in a sealed container. Trace elements were dissolved in water and bottled.

In the final preparation, all ingredients were homogenized in a blender of about one-half gallon capacity. Quantities used were:

Condensed milk – five 13-oz. cans
Mazola oil mixture – 240 gm.
Casein-mineral mixture – 227 gm.
Trace elements – 10 cc.

The lecithin had been added as an emulsifying agent but experience showed that the blender would emulsify the oil without lecithin. The mixture formed a thick paste which was diluted 50 percent with water and stored in a refrigerator.

Feeding

Nine fawns were started on the improved formula on July 9, 1958. Three males and three females were raised successfully. The three deaths occurred because of injuries or causes unrelated to diet.

Fawns were fed twice daily from 8-oz. nursing bottles with nipples split to increase the flow of milk. Fawns readily accepted the formula. At first they consumed about eight oz. per feeding. Consumption gradually increased but was finally

[1] A contribution from the Federal Aid to Wildlife Restoration Program, Surveys and Investigation Projects, Missouri 13R.

limited to 16 oz. per feeding. No scouring or constipation occurred.

Grasses and forbs were available in the deer pen and calf starter was supplied on a free choice basis. Fawns were permitted to wean themselves and all had done so by August 20. After weaning, the fawns were fed calf starter and corn until mid-December. Purina Dry and Freshening Chow was then substituted for the calf starter. Alfalfa hay was supplied but very little was consumed.

GROWTH OF FAWNS

Growth of the fawns indicated that the formula supplied an adequate diet. Mid-November weights of the experimental fawns were comparable to weights of fawns killed by hunters on the better soil types in Missouri.

The penned fawns averaged 14.0 lb. on July 1. They averaged 65.7 lb. on October 15, an average gain of 51.7 lb. Average daily gain was 0.48 lb. Nichol (1936) reported a gain of about ⅓ pound per day for white-tail fawns raised in captivity in Arizona. However, since does producing and nursing the fawns were on experimentally restricted diets, growth of the fawns may have been restricted.

BREEDING OF FAWNS

Further proof of adequacy of the diet was supplied by the experimental females. All three females bred successfully and each produced a single fawn the following summer when the females themselves were only 1 year old. McDowell (1959) stated, "In this regard, the writer has read, or knows through correspondence and conversation, of no authentic incidence of pregnancy among captivity-reared white-tailed fawns." Severinghaus and Cheatum (1956) reported that breeding of fawns was correlated with quality of range and thus assumedly with nutritional level. They also stated, "The fertility of an animal appears dependent upon energy sources in excess of those required for mere survival of the animal." Breeding of our experimental fawns indicates that the ration supplied to them was adequate for both growth and reproduction.

ANALYSIS OF MILK

The formula described in this paper was based on analyses of black-tailed deer milk. Knowledge of the composition of white-tailed deer milk was needed for comparison. Analysis of milk from one of our lactating yearling females showed that milk from the two species was quite comparable.

One of the yearling females, in her third week of lactation, was penned away from her fawn in the evening. The following morning, the doe was caught and anesthetized with sodium-pentobarbital. One cc. of oxytocin (let-down hormone) was injected into the mammary vein. The teats were then stripped by hand. Another cc. of oxytocin was injected subcutaneously when the supply of milk diminished, and milking was continued until all teats were dry.

TABLE 1.—COMPARISON OF WHITE-TAILED DEER MILK WITH MILK OF OTHER SPECIES

Species	Percentages of Whole Milk				
	Protein	Fat	Ash	Lactose	Total Solids
White-tail (present report)	7.04	7.3	1.48	4.28	20.1
White-tail (Ruff, 1938)	11.92	15.06	1.51	3.75	32.2
Black-tail (Kitts, *et al.*, 1956)					
Sample #1	9.56	10.5	1.56	3.91	25.1
Sample #2	8.96	10.5	1.30	4.67	25.4
Sample #3	8.14	10.2	1.62	4.55	24.5
Black-tail (Hagen, 1951)	*	8.3	1.44	*	20.4
Mule deer	*	8.1	1.66	*	20.8
(Browman and Sears, 1955)		8.4	1.50		22.3
		13.6	1.39		27.6
Cow (Kitts, *et al.*, 1956)	3.8	4.4	0.7	4.9	13.8

* Not reported.

We obtained 610 cc. of milk, weighing 628 grams, with a specific gravity of 1.032. The milk was stored in a freezer and kept frozen until analyzed. Table 1 compares the presently reported analysis of white-tailed deer milk and previously reported analyses of milk from other species.

The analysis of Missouri white-tailed deer milk compares more closely with analyses of mule deer and black-tailed deer milk than with the composition of white-tailed deer milk reported by Ruff (1938). However, Ruff's samples were collected post mortem from adult females during a November hunting season. The females were in advanced stages of lactation, presumably post-weaning.

Only Kitts, *et al.* (1956) reported on milk collected from a living female. Our analysis of white-tailed deer milk does not agree exactly with their analysis, but our findings do indicate that white-tailed deer milk is considerably richer than cow's milk. The formula we use for rearing fawns at least approximates the composition of white-tailed deer milk.

SUMMARY

A formula which enriches condensed milk to approximate the composition of deer milk is suggested for feeding captive fawns. Six fawns were successfully reared on the milk substitute. The formula provided adequate nutrition for both growth and reproduction.

Analysis of white-tailed deer milk showed that it is comparable to the milk of other species of deer in the United States.

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BOOK REVIEWS

Quail and Partridges of North America, A Bibliography. By Charles G. Crispens, Jr. University of Washington Press, Seattle. 1960. xii+125 pp. $3.25.

Two thousand one hundred bibliographic references from 72 North American journals are presented for 8 species of quails and 2 species of partridges. The number of references for each of these gallinaceous birds is: bobwhite quail, 1086; California quail, 252; Hungarian partridge, 226; chukar partridge, 137; Gambel's quail, 63; scaled quail, 41; mountain quail, 29; coturnix quail, 22; harlequin quail, 18; and singing quail, 11. In addition, there are 215 references on quails and partridges in general. References on bobwhite quail, California quail, and Hungarian partridge are arranged under captions pertaining to food habits, life history, mortality factors, management, reproduction, and miscellaneous. The 1564 references for these 3 species comprise nearly three-fourths of the book (88 pages). The wide range in number of references among these 10 species indicates the differential research emphasis on these birds, and it shows which species are most important to hunters, since they pay for most of today's research on wild animals.

The accelerated rate at which new scientific publications are being introduced, and the resulting compounding of information, pose a growing and vital problem to the investigator. Bibliographies alone are not a complete solution to this problem, but they help. Crispens' compilation provides a very useful service to those who are interested in quails and partridges; it is hoped that it will stimulate others to undertake similar projects, and that it will focus attention on those species which have not been studied intensively.—IRVEN O. BUSS, Department of Zoology, Washington State University, Pullman, Washington.

Science and Resources: Prospects and Implications of Technological Advance. Edited by Henry Jarret. The Johns Hopkins Press, Baltimore. 1959. xiii+250 pp. $5.00.

During the last 10 years a great number of books and papers dealing with the future availability of natural resources have been published. The predictions about the availability and use of resources appearing in these publications rest on a series of assumptions which include estimates of future population levels, economic states, conditions of transportation for moving resources from producing to consuming areas, rates of use of resources, discoveries of new reserves of nonrenewable and the growth of renewable resources, and, finally, discoveries by science which will allow us to use new or old resources in new ways. Clearly there is wide latitude here for various interpretations of future requirements. *Science and Resources* aids us in evaluating some of these estimates by presenting a series of objective discussions by scientists and economists on the applications of advances in six areas of science and technology to resource management.

Science and Resources is another publication from Resources for the Future, Incorporated, and in style follows their earlier *Perspectives on Conservation.* Each of the papers was presented at a public meeting in Washington, D. C. and, as is usual in a collection of this nature, not all the participants deal with the problem under discussion. This is particularly true in the first section, in which George Beadle presents a clear and simplified account of the advances in biochemical genetics but only briefly touches on the applications of genetics. The other sections are more to the point and each of these is considered briefly below.

Horace R. Byers in a discussion of weather modification traces the history of cloud seeding to increase precipitation. Although rain-making has enjoyed wide popularity, our knowledge of the

basic mechanisms of cloud and rain formation is very limited. It is so difficult to predict the quantity of rain expected to fall normally that it is hard to judge if cloud seeding actually increases precipitation. Presumably manipulation of the weather could benefit mankind; however, without knowledge of the result of weather manipulation the effect could be disastrous.

The depletion of mineral supplies has been a recurrent topic of concern in many books and papers on the conservation of natural resources. John A. S. Adams, in the section on exploration of minerals, is optimistic about our ability to find new stores of vital minerals. Apparently there is little reason to expect that we will exhaust deposits of minerals in the near future. However, it will probably be necessary to utilize lower grade ore and ore located deeper in the ground, and these ores will require more energy per pound extracted and refined.

The fourth section, on chemical technology, is especially significant since so many of the recent advances in technology have come in the chemical industry. Earl P. Stevenson, in discussing some of these advances, suggests that to achieve continued economic growth and development we must want and consume more of the products of our industries and laboratories. He considers the fact that the industry of want-creating (advertising) has approximately the same annual expenditure as technical research is a sign of a healthy economy. Even if one might argue with Stevenson's economics, it is true that chemical technology has made great strides and will probably continue as a dominant influence in our national economy. Increasing materialism does not necessarily mean a decline in culture. Actually the contributions of science and chemical technology have made cultural, nonmaterial resources increasingly available to great segments of our population.

Supply of energy may be a limiting factor to future growth; will nuclear energy be the answer to the power problem? In the fifth section, Willard F. Libby evaluates the ability of nuclear power to replace conventional sources of energy. Part of the problem of converting industry to atomic power is the supply of uranium required. To produce 100 million kilowatts of electricity based on nuclear energy (in 1953 the U. S. produced approximately that amount of electricity) we would require all of the U^{235} in 15,000 tons of uranium—we now purchase 30,000 tons of uranium oxide annually. Since additional uranium would be needed in inventories and other uses, these 30,000 tons might not be enough to support a large increase in atomic power. Possibly we will find new deposits of uranium and new sources of fissionable fuel to meet future power requirements.

In the final section, on outer space, Lee A. DuBridge makes the amusing observation that outer space is not only plentiful, it is also durable and never gets used up. We humans faced with increasing populations on this planet often seriously consider the possibilities of colonizing or, at least, of obtaining natural resources from outer space. DuBridge points out that these ideas are extremely visionary because of the great distances involved. For instance, a vehicle travelling 90,000 miles per hour would take 30,000 years to reach Alpha Centuri, the nearest star. DuBridge suggests that the greatest resource to be gained from outer space is new knowledge.

In each of the fields considered in this volume more knowledge is required before we can adequately evaluate future resource requirements. There is little reason to expect that we will ever have all the information we require—possibly there is a general law that, as mankind evolves, a greater proportion of his material wealth is expended in creating new knowledge. The problem that faces us today is, I think, concerned equally with the allocation of research funds and with obtaining funds for new research. For instance, Alan Dean in the section on outer space states that about 10 percent of total federal expenditures for research are presently allotted to space activities. In the face of competing requirements from other projects should expenditures for space be increased? These questions require some kind of national planning and delimitation of goals before they can be answered.

I am encouraged that several of the writers express a concern for the proper use of human resources. It seems to me that this is the crux of the conservation problem and one area to which we should devote a greatly increased amount of attention. Are we educating and utilizing our people to the limits of their abilities? Are we maintaining the ethical, moral, and esthetic values of our culture while we advance scientifically? Perhaps Resources for the Future should sponsor a third book to consider the problems of conserving human resources.—FRANK B. GOLLEY. Department of Zoology, University of Georgia, Athens, Georgia.

Alaska in Transition: The Southeast Region. By George W. Rogers. Johns Hopkins Press, Baltimore, Maryland. 1960. xiii+384 pp., 25 black and white plates, 47 tables, 11 text figures, 2 appendices. $7.00.

Dr. George Rogers is a scholar with a sly sense of humor. This lucky combination results in a highly readable book which skillfully weaves the sciences of sociology, anthropology, and natural resources management with the art of political intrigue into the mosaic which is southeast Alaska in transition.

The principal theme of this book is the Region on the threshold of a future quite different from its past. The past is reviewed in terms of its geography and geology, natural resources, human resources, political manipulations and "outside-oriented" exploitation of the resources. The basic issue underlying the future of southeast Alaska's development is the determination of whether the

Region's natural resources will continue to be exploited by and for nonresident interests or whether Alaska's new statehood can develop the esprit to attract capital for resident-oriented development.

The book is more than intriguing history, however. It is a well-documented record of overexploitation of renewable natural resources (fur and salmon), and an indictment of those agencies and individuals responsible. The book does more, also, than merely lament man's avarice. It offers the prescription by which he can heal a sick fishing industry, nurture a lusty, young timber industry, and husband a nonrenewable mineral resource. As the author variously states or implies, the foresters, biologists, geologists, sociologists, and other technicians either have, or can get, the answers for proper management. What is needed now are farsighted and practical state leaders to implement and enforce management practices in the best interests of the resources which, in the final analysis, will be in the best interests of the resident population.

The book is very attractively illustrated with 25 well-chosen black and white photos and 6 maps. It includes 47 tables of documentary data plus 2 population and economic appendices. There are 306 footnotes citing about 150 different authorities and sources of information, all of which attest to the scholarly approach the author has taken.

The book contains no bibliography. This would be a desirable feature in addition to the references provided in footnotes. The citations could either be listed alphabetically at the end of each chapter or consolidated in one bibliography at the end of the book.

As stated in the preface, "The present volume is part of a broader study being conducted of Alaska in transition, and thus serves as a pilot study for the work now being conducted by Dr. Rogers under the auspices of the Arctic Institute of North America and Resources for the Future." If the rest of the journey through Alaska follows the same scholarly path as this, the pilot study, the trip will be well worth the time of all those interested in the welfare of America's greatest storehouse of natural resources.—HENRY A. HANSEN, U. S. Fish and Wildlife Service, Juneau, Alaska.

Behavior and Evolution. By Anne Roe and G. L. Simpson. Yale University Press, New Haven. 1958. viii+557 pp.

This book represents an unusual and gratifying approach to the problems of publishing symposia. The Society for the Study of Evolution and The American Psychological Association sponsored a multidisciplinary exploratory conference in 1955 concerning the status of theory and data of behavioral evolution. From this conference plans were made for a second and publication-oriented symposium. The second conference was primarily devoted to critical discussion of the previously distributed papers that are chapters of this book. Thus, except for the opening and closing chapters, each one was revised and edited after it had been discussed by 32 scholars from various social and natural sciences. The introduction to the book and to each of the 5 sections, and Simpson's very fine Epilogue provide exceptional clarity and coherence.

In Part I, Simpson presents one of the most concise and satisfying purviews of evolutionary theory and method that this reviewer has seen. It is followed by chapters by Colbert, who is concerned with postdicting behavior from fossil morphology, and by Romer. Romer's treatment of vertebrate behavioral evolution implicitly follows a "function follows form" orientation.

In Part II, Beach argues that evidence for endocrine evolution is in the development of target organs, and among mammals, in the corticalization of function. Caspari deals with the genetics of behavior, emphasizing the pleiotropic action of genes, whereby apparently useless morphological characteristics have genic ties with adaptive behaviors and vice versa; and heterosis. Sperry reminds us of the very subtle operation of genic factors in ontogeny, whereby the highly complex as well as simple responses may be "inherited." Pribram emphasizes the too frequently ignored fact that the evolution of the vertebrate forebrain has no clear relation to complexity of behavior, but is associated with a trend towards its multiple determination. He clearly distinguishes the excitatory functions of the internal core of the brain, and information-collating function of the cortex as related to evolution. Bullock in the succeeding chapter points out that there is no essential difference in the neurophysiology of simple metazoans as compared with higher vertebrates; hence evolutionary advances in behavior must be sought partly in the complexity of neural connections, but largely in new parameters of neuronal activity. Pioneers, take note.

Part III, "Categories of Behavior," begins with a thought-provoking paper by Nissen on behavioral classification. He concludes, somewhat weakly, that principal phyletic behavioral differences are to be found in integrative, as opposed to receptor, effector, or motivational mechanisms. Bates discusses food-getting, and argues with apparently little conviction that this would represent a fruitful behavioral system for the synthesis of data on behavioral evolution.

The concept of territoriality is well covered by Carpenter, although his application of the concept to evolution is exceedingly speculative, general, and brief. Hinde and Tinbergen write of species-specific behavior. Curiously, perhaps, these ethologists summarize their orientation and document its value in one of the shortest chapters in the book. Yet the reports of experimentation and observation from the ethological standpoint are voluminous. Harlow does not see evidence for any qualitative changes in learning in evolutionary history, although a rough increase in learning capacity is discernible. An animal, he argues, learns to inhibit responses that interfere with achievement of re-

ward. It does not learn, in any positive sense, the reward-oriented response.

The chapters by Thompson and Emerson emphasize the interactive influence of vertebrate and insect social behavior and evolution, but lament the dearth of data, particularly with regard to hominid social behavior.

Part IV is specifically concerned with the importance of behavior in the study of evolution, rather than vice versa. Mayr, speaking as a systematist, argues for greater attention to individual differences, for dealing with populations rather than types. Spieth presents a beautifully documented picture of the role of sexual behavior as an isolating mechanism in closely related sympatric species. The chapter by Pittendrigh deals with behavior, adaptation, and natural selection with particular reference to *Drosophila* in various microclimates. He stresses the directing influence of behavior on evolution.

The evolution of human behavior is the topic of Part V. Washburn and Avis, relying largely on australopithecine fossils, adopt a partial "form follows function" orientation, when relating the beginning of tool use to expansion of the brain case. Huxley's chapter is really an optimistic cultural commentary, remarking on where mankind has been, where it is going, and how. His particular theme is the evolution of culture oriented toward the changing of culture, as opposed to simple adaptation to a changing world. Freedman and Roe temper Huxley's optimism, somewhat, with the thought that man's increased potentiality for furthering mankind also contains the seeds of his destruction. Their treatments of sexuality, aggressivity, and acquisivity depict the frequently nonadaptive evolutionary residue in the individual of propensities that were and are advantageous for mankind. Mead explicitly points out that cultural evolution may be in the service of biological evolution, but is only analogous to natural selection. Simpson's closing chapter is a small masterpiece, tying together the contributions of the various authors.

The difficulties with symposium publications have not been entirely avoided. The level of presentation is somewhat irregular (*cf.* Huxley and Pribram); the documentation of argument varies in adequacy (the Spieth and Emerson chapters are outstandingly good in this respect); and the relative stress on behavior vs. structure differentiates the participants (*cf.* Romer vs. Pittendrigh). Romer, Sperry, Pribram, and Carpenter all present arguments that simply could not be adequately developed and documented in the allotted space. Consequently their presentations are not entirely convincing. The difficulty is in the stringencies of publication, not in the quality of thought or availability of supporting data.

There are, to be sure, a few errors, such as documenting a statement about pigeons with a reference concerning sunfish, but these are rare. Also rare are careless assertions about the comparative behavior of dogs and cats (Colbert), learning in earthworms or color vision in mammals (Harlow), territorialism in invertebrates (Carpenter), etc. These assertions most certainly represent unfamiliarity with certain areas of the literature.

Behavior and Evolution is in part an antidote to provincialism and an opportunity for growth by providing the reader contact with an enormous fund of diverse data and thinking. It is immensely valuable in pinpointing the broader implications of evolution, in serving as a source of testable (and other) hypotheses, in defining gaps in our knowledge, and pointing to new directions in research. There are really no new insights to be found in the book. On the other hand, almost everyone will find something new. Perhaps the new insights will come from the readers.—F. D. KLOPFER, Department of Psychology, Washington State University, Pullman, Washington.

La Quaglia–Vita–Allevemento, Caccia. By Augusto Toschi. Suppl. all Ricerchedi Zoologia Applicata alla Caccia, Vol. III, Numero unico–Laboratorio di Zoologia, Universitadi Bologna. 1959. 267pp., 55 photog. plates, 2 in colors. Price L. 900.

The Department of Zoology of the University of Bologna (the oldest university in the world) has for many years been a center of study of the game birds, due to the influence of the professor in charge, Dr. A. Ghigi, now retired after a long career, the last 20 years as Rector of the University. Professor Toschi, a close associate of Ghigi, has specialized in the biology and practical management of the game birds. The subject of the present book is the Old World quail, its life and habits, in breeding and hunting. Only the more closely allied species and subspecies of the genus *Coturnix*: *coturnix, japonica, africana, delagorguei, coromandelica,* and *pectoralis,* are included (another species of the group, *novoae zelandiae,* is extinct). The survey is exhaustive and full of information. The first chapter defines the position of the quails in the bird order; the second, their geographical distribution and diffusion; the third, their shape and structure; the fourth, their biology, a long chapter of great interest. The fifth and last, also bulky (138pp.), is a detailed study of the bird's economic value and includes its propagation, its value to the sportsman, and the different hunting practices in the various countries where quails live or have been introduced. A bibliography is found at the end.

Professor Toschi's work is remarkable in its completeness and reflects a great deal both of personal experience and research. It is beautifully produced and illustrated. All those who are interested in quails, and who can read Italian, will find a mine of accurate information, and no doubt gain considerable knowledge in reading Professor Toschi's excellent treatise.—J. DELACOUR, Director, Los Angeles County Museum, Exposition Park, Los Angeles 7, California.

Fresh-Water Biology, Second Edition. By H. B. Ward and G. C. Whipple (W. T. Edmondson, Editor). John Wiley and Sons, New York. 1959. xx + 1248pp. $34.50.

The second edition of Ward and Whipple's *Fresh-Water Biology* is a generally successful attempt to revive and extend the usefulness of a guide which has long beeen recognized as inadequate. The second edition covers all of the groups included in the first edition, except vertebrates and internal parasites. Some groups (e.g., Tardigrada and Bryophyta) are newly included, and others (e.g., Bacteria) are given much more extensive treatment. Most of the general biological and ecological information of the first edition has been omitted since extensive information on those subjects can be found in recent references.

The introduction of *Fresh-Water Biology* describes the organization of the book, and most important, gives detailed instructions on the use of the keys. Chapter 2 is an "introduction to the Protista" by Dr. R. Y. Stanier, which is very compact and informative. The following 43 chapters are, essentially, illustrated keys to the various groups of fresh-water organisms included. Almost every chapter also contains discussions of taxonomic characters used in the keys and methods of collecting and preserving specimens. Each chapter contains a section in which are placed references to works giving more detailed or supplementary information on the systematics and/or biology of the group under discussion. In the final chapter (46) are discussed general methods and equipment useful in collecting and studying many fresh-water organisms. Sources for more detailed information on methods and equipment and addresses of suppliers of newer, specialized, materials mentioned in the text are also indicated.

The format of *Fresh-Water Biology* is very effective. In view of the fact that the book is the product of some 51 contributors, this effectiveness is attributable to an excellent job of editing by Dr. Edmondson. The illustrations throughout are quite good. The keys are simple, straightforward, and therefore very useful.

This review was undertaken with the full realization that a single taxonomic specialist usually does not have sufficient knowledge of groups outside his specialty to permit him to speak with authority on those groups. Therefore, with the exception of the malacostracan Crustacea, the reviewer has based his opinions concerning the utilitarian value of *Fresh-Water Biology* on the ease with which specimens (which had been determined previously) could be "keyed out," using the keys in the appropriate chapters. The success of this venture was a reflection of two factors: (1) the amount of work which has been done on the systematics of the various groups represented, and (2) the completeness with which the groups are covered by *Fresh-Water Biology*. Thus local Cladocera were easily keyed to species. Local turbellarian flatworms, crayfishes, asellid isopods, copepods and gastropod molluscs were easily keyed to family and genus. Only one known serious omission can be cited. The Pacific Coast large clams are adequately described and illustrated in a paper by W. Ingram (*J. Ent. and Zool.*, 40:72–92, 1948), and that work is neither included nor cited in the chapter on Mollusca.

In conclusion, *Fresh-Water Biology*. second edition, is a masterful piece of work. Any faults that it possesses undoubtedly can be traced directly to one (or both) of the two factors mentioned in the preceding paragraph. It should be emphasized that a reference of this nature can serve only as a guide (as adequately pointed out by Dr. Edmondson in the preface). Therefore, it is reasonable to expect (and hope) that the second edition of *Fresh-Water Biology* will stimulate a renewed interest in the taxonomy and systematics of fresh-water organisms.—J. A. RIEGEL, Department of Zoology, Washington State University, Pullman, Washington.

Grundlagen der Wildernährung. By Dr. Antonín Bubeník. Deutscher Bauernverlag, Berlin, D.D.R., 1959. 299pp., 18 text figs., 35 tables, 25 graphs, 26 appended figs. (half cloth, 8¼ × 6 in.) D.M. 14.20.

This book is said to be basically a translation of the author's "Krmeni lovné zvéře" published in Praha, Czechoslovakia, in 1954, but to contain much new information.

Game Nutrition, as we must call it, because it deals only with game species, is on the way to joining the European classics of game management. The orientation is towards the universal European practice of game feeding. However, the author starts out by saying that game nutrition must not be based on studies of domestic animals, but rather on the natural conditions of activity, food habits, and social behavior for the species concerned. He gives a brief outline of nutritional physiology in general, and then a statement of its application to game, both furred and feathered, both in the general and in the special sense. Finally, nutritional information is given for the important game of central Europe. This includes digestive anatomy, specific application of the physiological information, food seeking and feeding habits of the animals, the various types of feed and many considerations relating to them, and the relationship of the whole to artificial feeding. One moves through the year, and through the sexual and life cycles as required. Conspicuously absent are discussions of the biology of overpopulation and the physiology of starvation. You will, however, find discussions of such things as population density and nutritional deficiencies. There is a special section at the end on feeding shelters and food dispensers. The discussion of nutrition is far more extensive than that in our species texts. Even if it were not, the comparative information would be invaluable. A sec-

tion on the improvement and storing of game feeds includes procedures for range improvement.

As a long-time worker in game research at the Institute of Forestry and Wildlife Management in Praha, Dr. Bubenik has specialized in physiology. His writings have been most original and provocative. He is the sort of man who will ask one for information that should be available, but of which one is forced to reply: "We don't know." This reviewer's German has seldom got him past the first beer, yet he had no trouble with this book. There must be few wildlifers to whom it would not be useful if they would make the effort to read it, and it is so concise, and the paragraphs are so well organized and captioned, that anyone with access to a dictionary should be agreeably surprised at his ability to use it.

My chief criticism is of the bibliography, which is so sketchy that it is hardly worth printing. One notes, for example, with not a little interest, that there is obviously a book, paper, or report of some sort, published in Russia, on the role of snow cover in the life of antlered game, and another on wild rice; but even if one had full access to all the publications referred to, it would be difficult to find the works cited.

The author obviously feels that the knowledge of his subject is fragmentary, and that the really basic research not only in game nutrition, but in such related subjects as carrying capacity, remains to be done. His closing word is an appeal to both scientists and sportsmen for more basic research. —C.H.D. CLARKE, Department of Lands and Forests, Toronto, Ontario.

Wildlife of Mexico/the Game Birds and Mammals. By A. Starker Leopold. University of California Press, Berkeley. 1959. xiii + 568pp., 194 figs. $12.50.

The usual pattern for a book review is a critique in which the reviewer points up errors of fact and typography, calls attention to faulty conclusions and in general "rakes the author over the coals." I have rejected this approach here because my own observations and study of wildlife in Mexico are completely in accord with Leopold's findings. I, too, have traveled extensively in Mexico and I, too, have seen the *campesino's* dire need for the bare necessities of life, and the scarred hillsides, ravaged woodlands, and depleted wildlife populations that have resulted from his endeavor to improve his lot.

Wildlife of Mexico is the culmination of studies begun by Leopold in 1944 when he initiated a survey of the wildlife resources of Mexico under the auspices of the Pan American Union and a branch of the Mexican government. The initial survey lasted 2 years, but this was supplemented during subsequent years by numerous shorter *vueltas,* all of which permitted him to gather first hand information on the fauna and flora in all major ecologic types of the Republic. In addition, the author took advantage of the vast fund of information that has been accumulated by other naturalists who have worked in Mexico. Consequently, the book is based on a broad foundation of personal knowledge and an impressive array of published reports. The bibliography contains 200 titles, most of which are concerned specifically with the Mexican flora and fauna.

The book is divided into three parts. Part I, consisting of five chapters and comprising about one-sixth of the volume, is concerned with "The Wildlife Resource and its Management." This section is a storehouse of information on the physiography of Mexico, vegetation zones, land-use practices and problems, utilization of wildlife resources as food and for sport, and the existing program of wildlife conservation. It ends with suggestions for a strengthened program of managing the wildlife of Mexico as a valuable national resource. Part I, to me, is the most important and thought-provoking part of the book, and it offers a real challenge to the Mexican people.

Part II is devoted to accounts of game birds as defined by Mexican game law, although, as the author points out, rural Mexicans actively hunt and utilize as food or as medicine a wide assortment of birds, including songbirds, woodpeckers, and even hummingbirds. Seventy species or species-groups of birds in the orders Tinamiformes, Anseriformes, Galliformes, Gruiformes, and Columbiformes are treated. Resident species are more fully discussed than wintering migrants.

Part III treats 51 species or species-groups of Mexican game mammals. The 6 species of fox squirrels are treated in one account as are the 10 kinds of gray squirrels, the 2 species of ringtails, etc.

The charcoal drawings by Charles Schwartz are useful, as well as artistic, aids to identification. The distributional maps, based on geographic probability plus museum records of known occurrence, permit one to delineate at a glance the probable range in Mexico of the species concerned. The numerous photographs are well-selected and useful additions. The English translation of the Mexican game code and hunting regulations (as of 1954), appearing in Appendices A and B, respectively, will be helpful to anyone interested in hunting in Mexico.

The book is well written, carefully edited (I noticed only one error—the misspelling of Microchiroptera on p. 8), printed on a good grade of paper and well bound. Both the author and the University of California Press deserve commendation for a job well done. This publication is not only indispensable to any serious student of Mexican game birds and mammals, but it is also a guide to all thinking Mexican citizens who are interested in managing a valuable resource through wise use. It sets a pattern that other Latin American countries might well strive to emulate.—WILLIAM B. DAVIS, Department of Wildlife Management, Texas A. and M. College, College Station, Texas.

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THE WILDLIFE SOCIETY

NOMINATIONS FOR PRESIDENT AND VICE-PRESIDENT, 1961–62[1]

President ..... E. L. Cheatum; W. Winston Mair
Vice-president ..... Jack H. Berryman; W. C. Glazener

[1] The full slate of officers and regional representatives will be included in the November *Wildlife Society News*.